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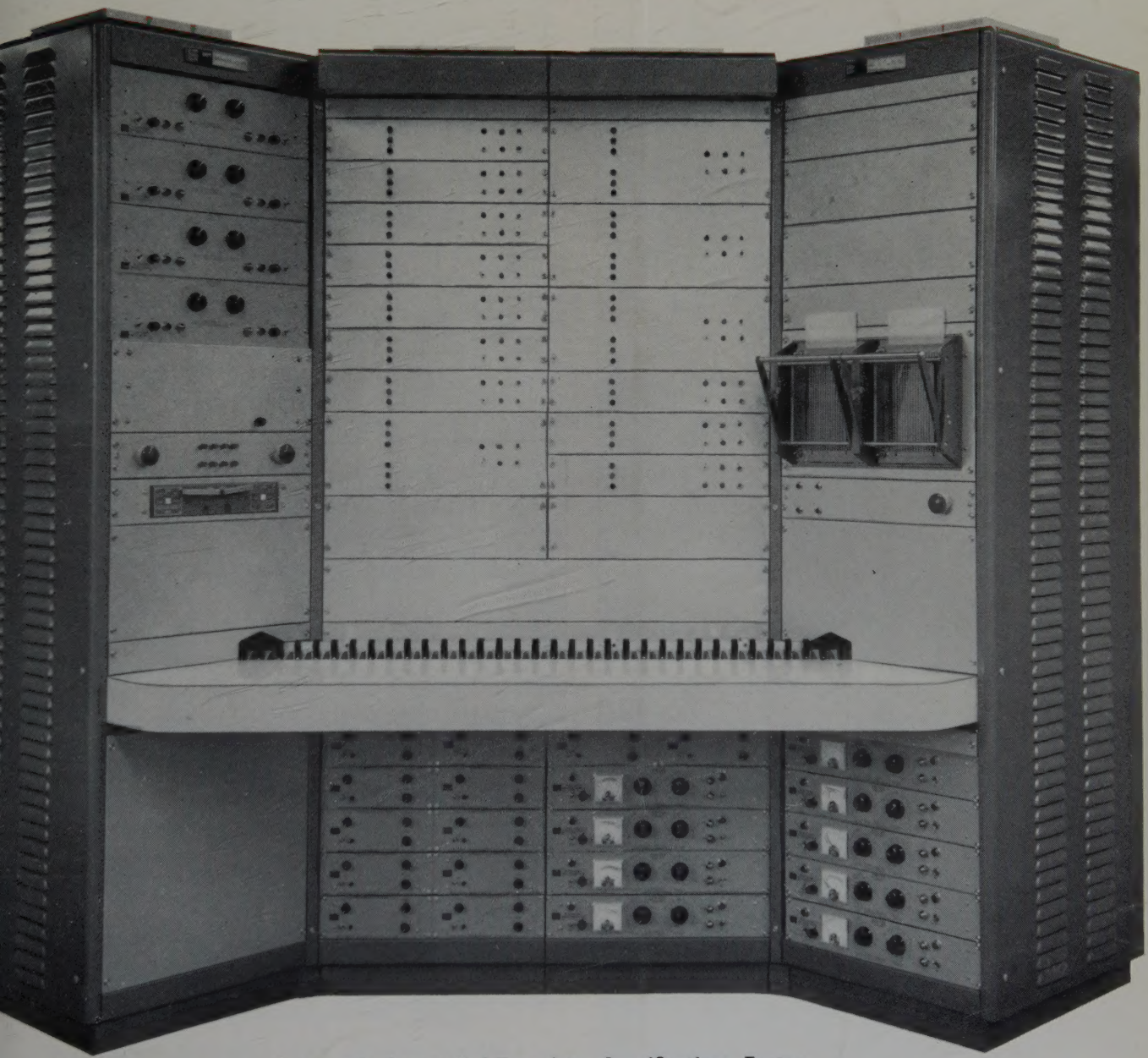

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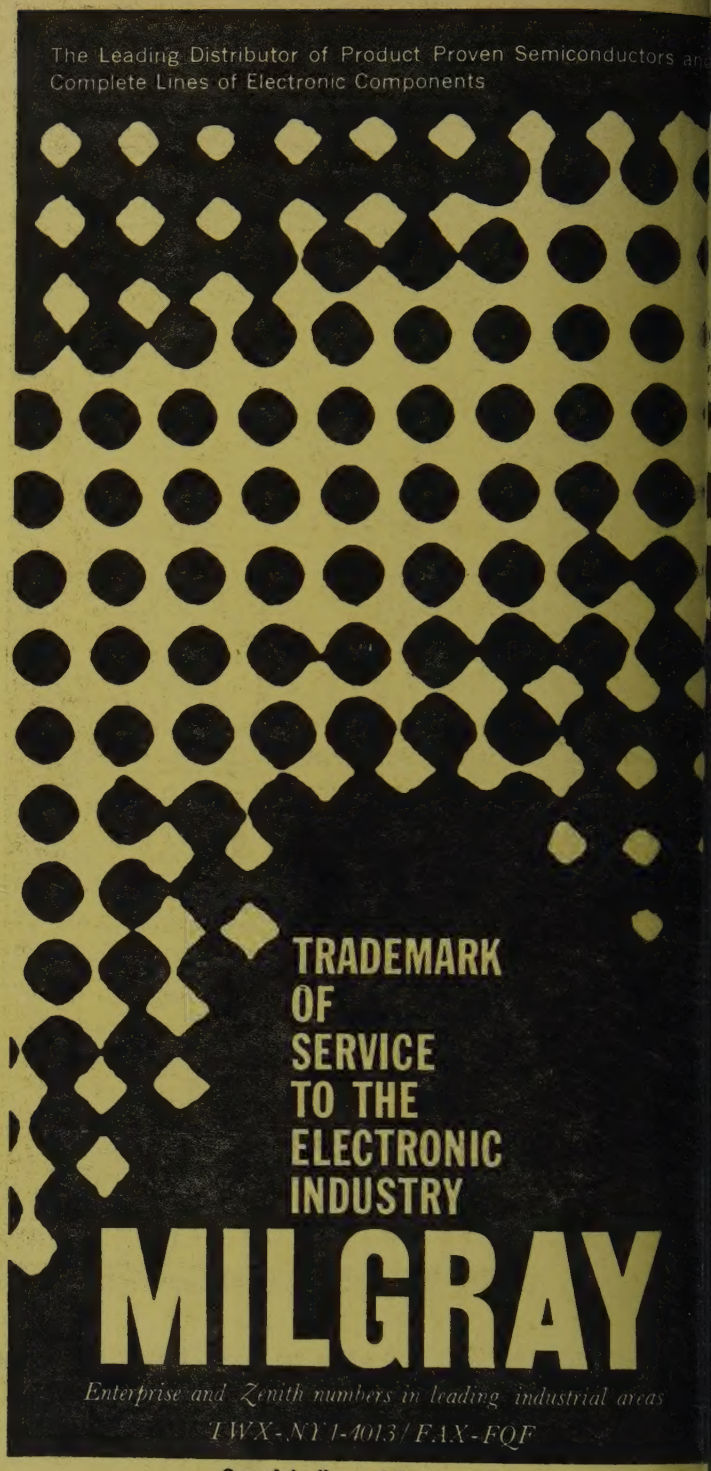

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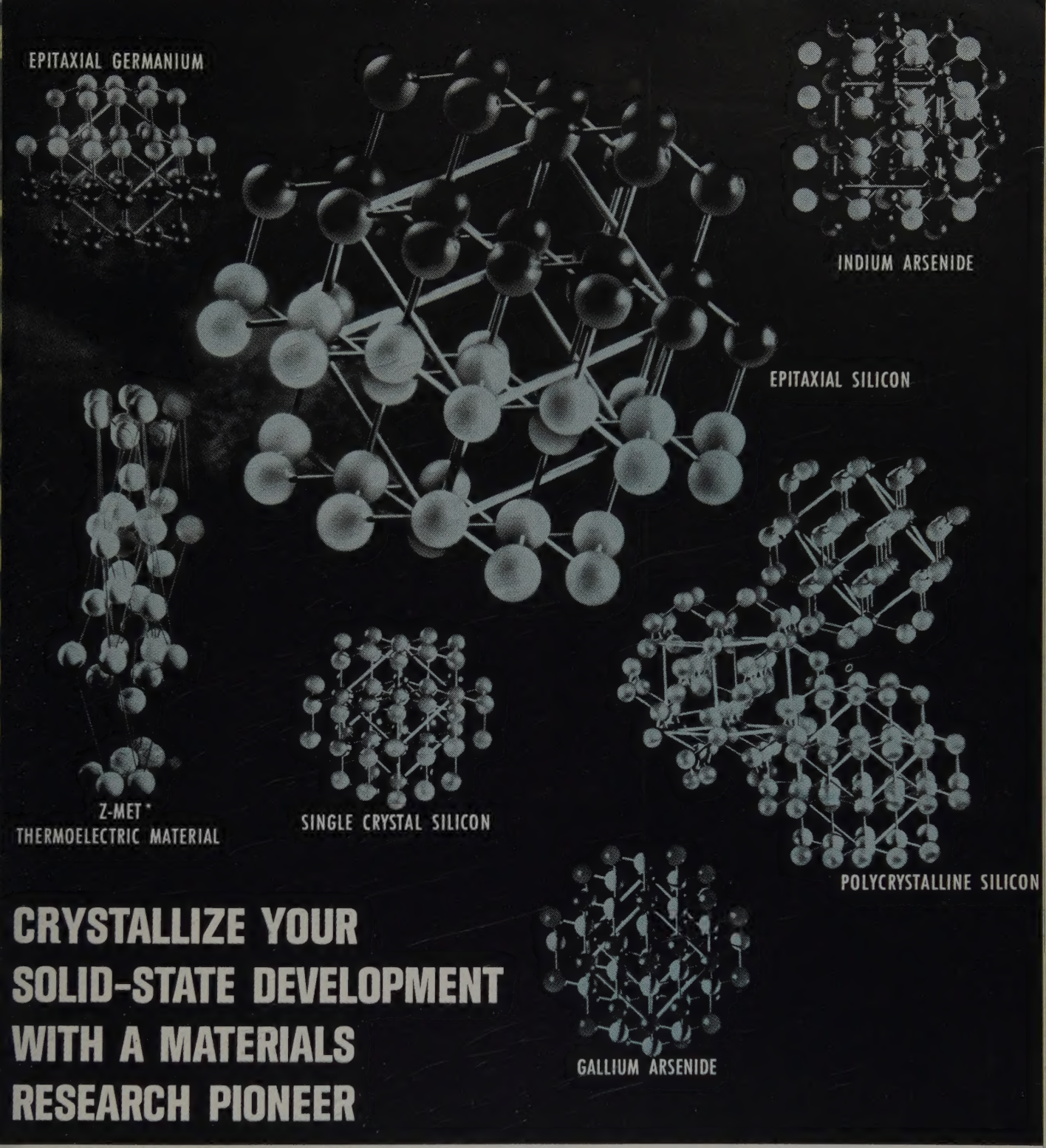

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SANFORD R. COWAN, Publisher

May 1961 Vol. 4 No. 5

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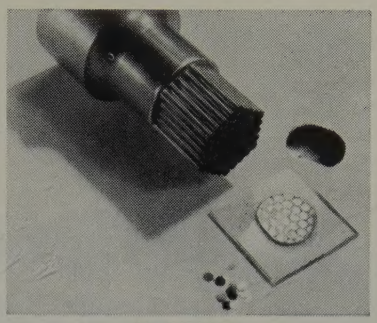

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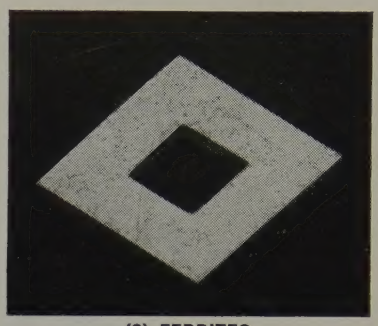

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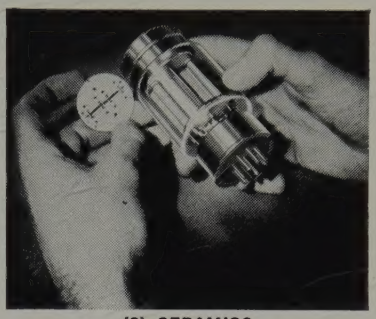

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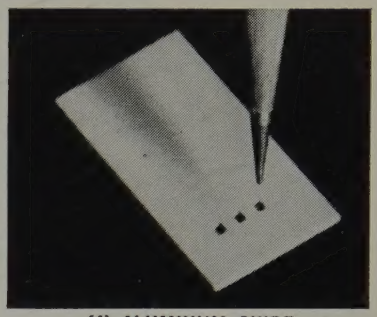

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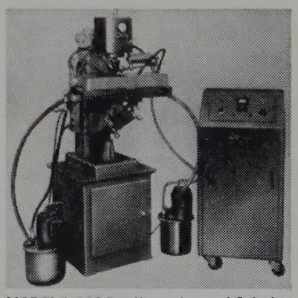

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The Untouchables (Part 3)

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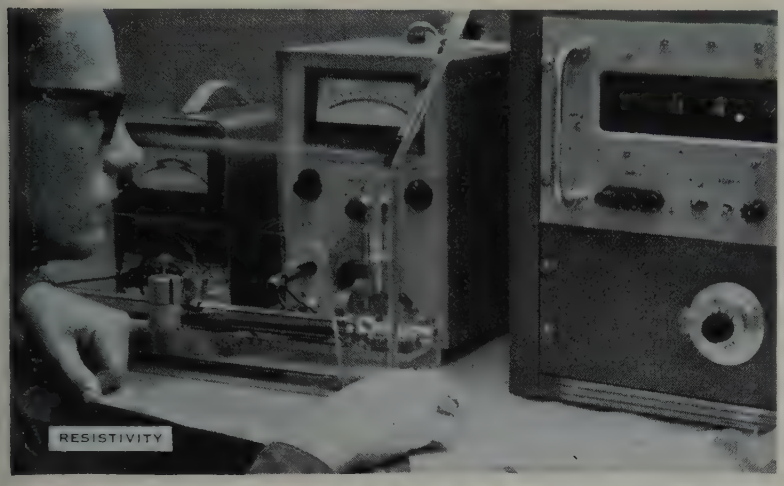

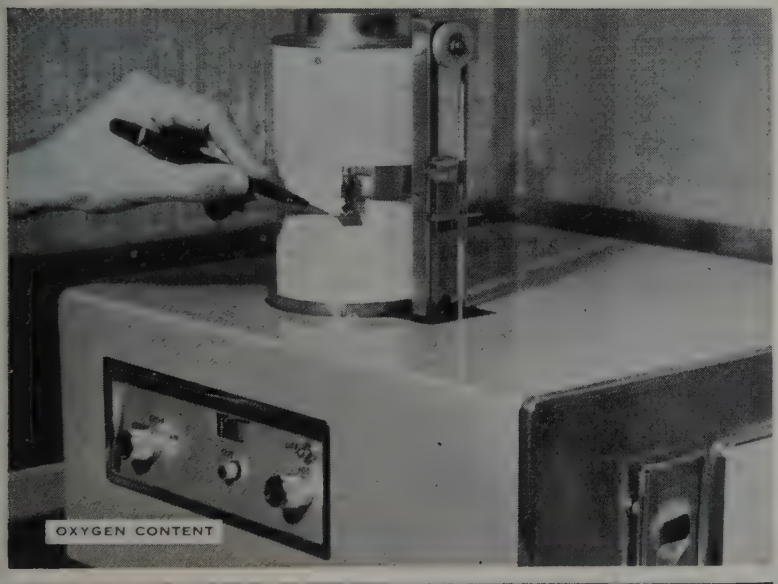

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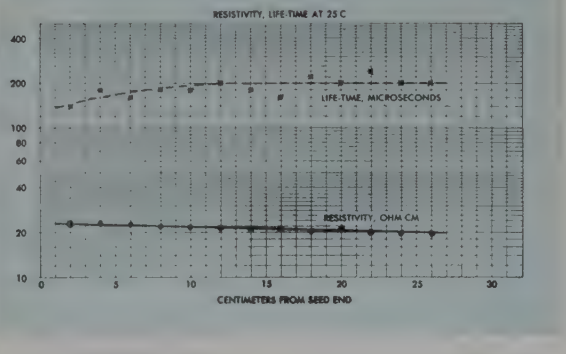

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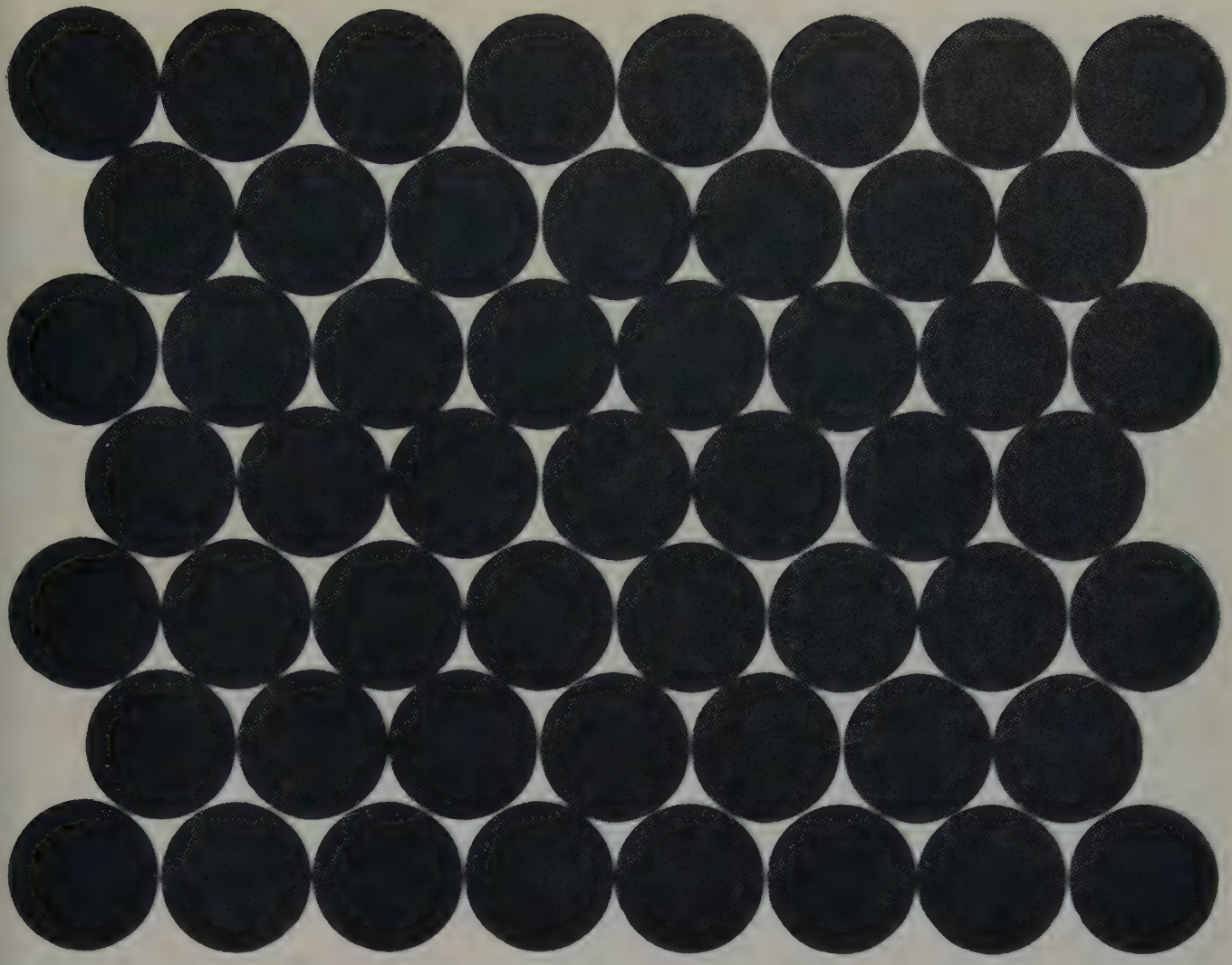

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(Part 4)

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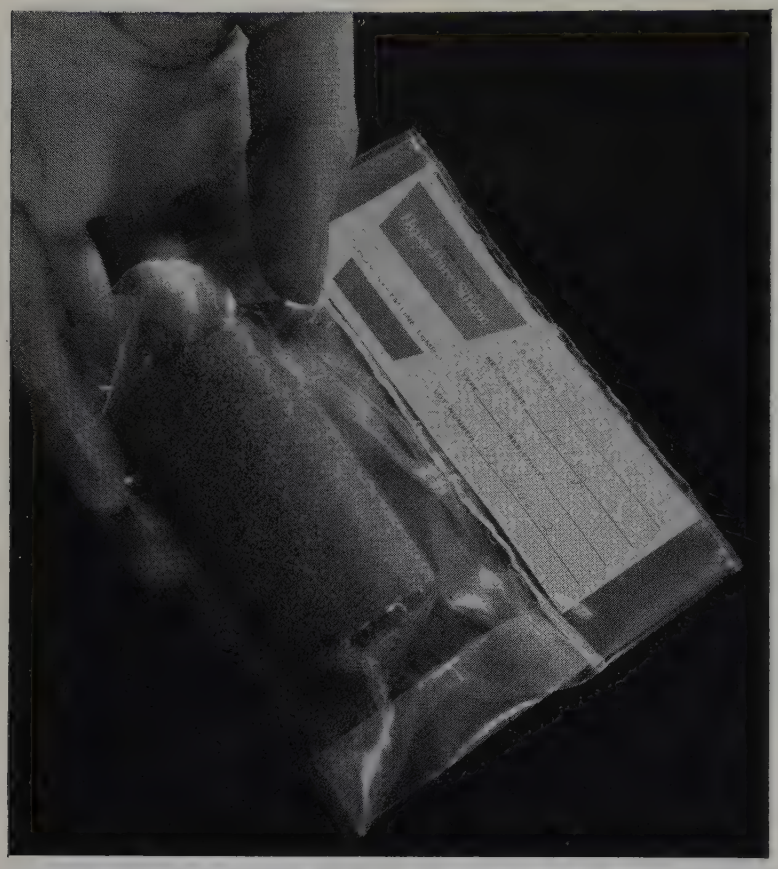

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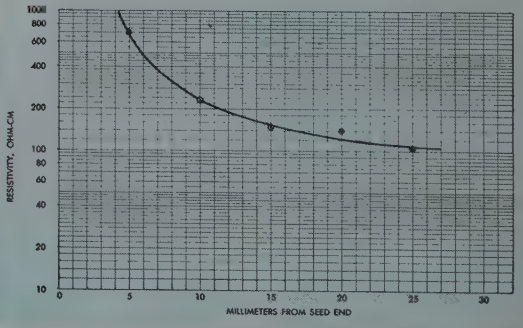

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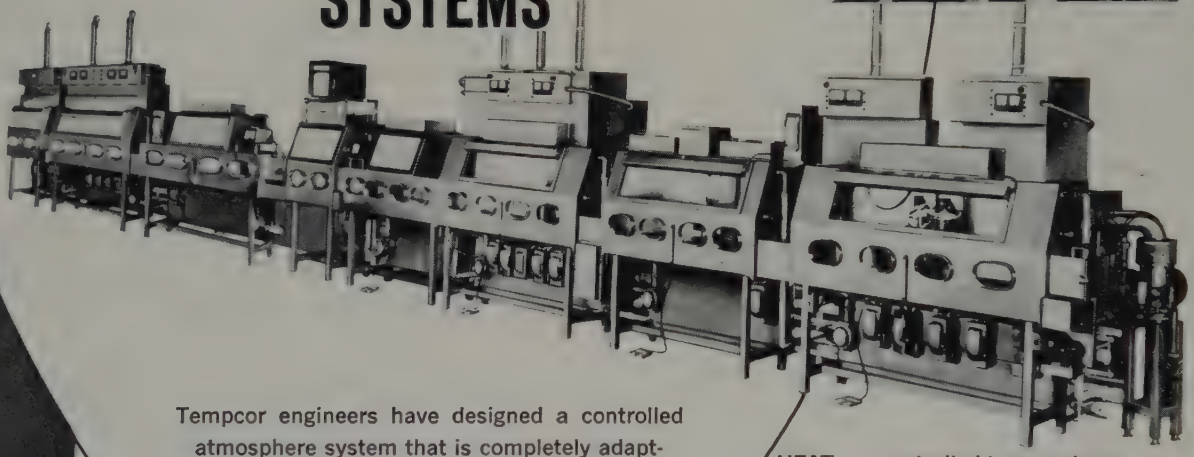

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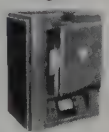

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* Semi Conductor Magazine Industry Report June 1961

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I would like further information on TEMPCOR CONTROLLED ATMOSPHERE SYSTEMS without obligation.

☐ Send representative
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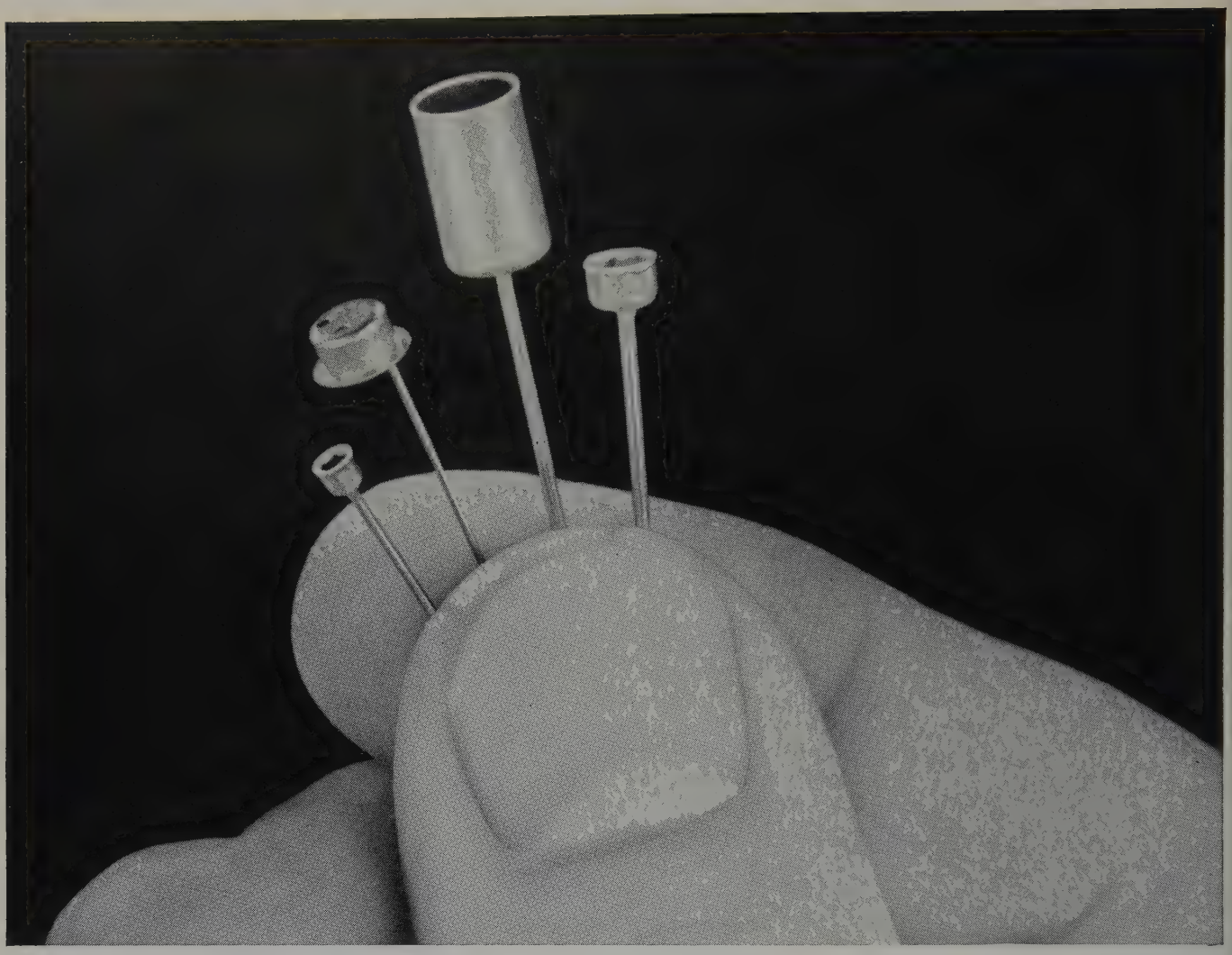

Now put your fingers on top-quality welded assemblies for semiconductors... by the millions!

Whatever you need in cup-to-lead and disc-to-lead semiconductors assemblies—and no matter whether they call for inside or outside welds—you can now obtain them from Sylvania at the rate of *millions per week!*

Here's why: Sylvania has just opened new production facilities that expand our capacity for automatic, semiautomatic and manual welding operations. These facilities can handle Dumet, Kovar, stainless steel, copper, "52 alloy" and other materials with maximum ease—even if your assembly is a miniature part.

Just as important: whether your job calls for manual or high-speed operations, the precise quality control that marks all Sylvania semiconductor parts assures better end-product performance.

Before you buy or specify, be sure you have a quote from Sylvania. For prices plus experienced engineering assistance, write Sylvania Electric Products Inc., Parts Division, Warren, Pennsylvania.

SYLVANIA

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GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

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Reduce Costly Kerf Losses

in slicing semiconductor material...

Now...switch to 3½" diameter diamond wheels to slice 1" diameter crystals on

Micromech WAFERING MACHINES

featuring the **NEW TYPE 2**

CARTRIDGE SPINDLE

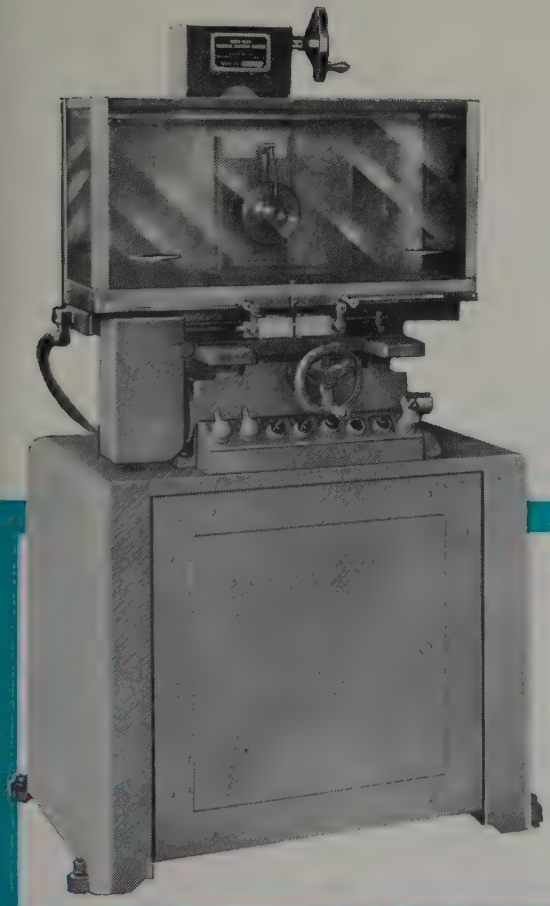
Micromech's newly-designed Type 2 Cartridge Spindle permits the use of thinner, smaller-diameter diamond wheels for slicing germanium and silicon. Provides top wafering efficiency with wheels of *all* sizes, too!

This specially-engineered spindle mounts a 3½" diamond wheel in place of the usual 5" wheel to give from 40% to 100% more slices per 1" diam. crystal . . . reduce kerf loss by 28% to 47%!

Micromech's 3½" diameter blades—in .010" thickness—can save from .004" to .009" per slice . . . add up to savings of $200.00 a day!

Moreover, the 3½" wheel allows cutting speeds up to 3" per minute . . . increasing production while decreasing loss of material.

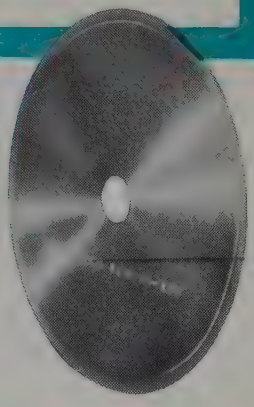
Type 2 Cartridge Spindle is now standard on Micromech mechanical and hydraulic automatic wafering machines. Write today for detailed information.



Micromech Diamond Wheels

Micromech stocks 3½" diamond wheels for the economical and fast slicing of all semiconductor materials.

Wheels also available in other popular and odd sizes, DIT and DITRS types. Precision manufacture to close tolerances assures accuracy of cut and long life.



MICROMECH MANUFACTURING CORP.

A Division of Sanford Manufacturing Corp.

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Specifically Developed for the Transistor Industry— Now Available in Drums!

ELECTRO GRADE HYDROGEN PEROXIDE

	Specification Min.	Max.	Typical Analysis
Assay: H_2O_2 % by weight	30.0 —	32.0	30.0 — 32.0
Free Acid (as H_2SO_4)		.003	.0006
Chloride		.001	.00004
Nitrate		.001	.00008
Phosphate		.015	.011
Sulfate		.0005	.0002
Ammonia		.001	.0006
Heavy Metals (as Pb)		.0001	.00002
Iron		.00005	.00001
pH glass calomel electrode 25°C (Beckman)	3.0 —	3.5	3.3
Stability (24 hrs. 100°C)	95		98

All figures in terms of % by weight unless otherwise noted.

—And Becco will work with you to help you design the system best suited to realize the economies—and quality standardization—inherent in bulk shipments.

Here's a new, stabilized 30% Hydrogen Peroxide, specifically developed for transistor etching—Becco Electro Grade H_2O_2, with pH value of 3.0 to 3.5. Made from pure electrolytic H_2O_2, this new peroxide is available in 30- and 55-gallon polyethylene drums to save you many dollars!

What's more, Becco engineers will work with you to help you design a closed system to guard against impurities. This means you get all the economies of bulk shipments...and assurance of a pure product at the same time. Whatever your needs, rely on Becco, *the* specialist in Hydrogen Peroxide for over 36 years!

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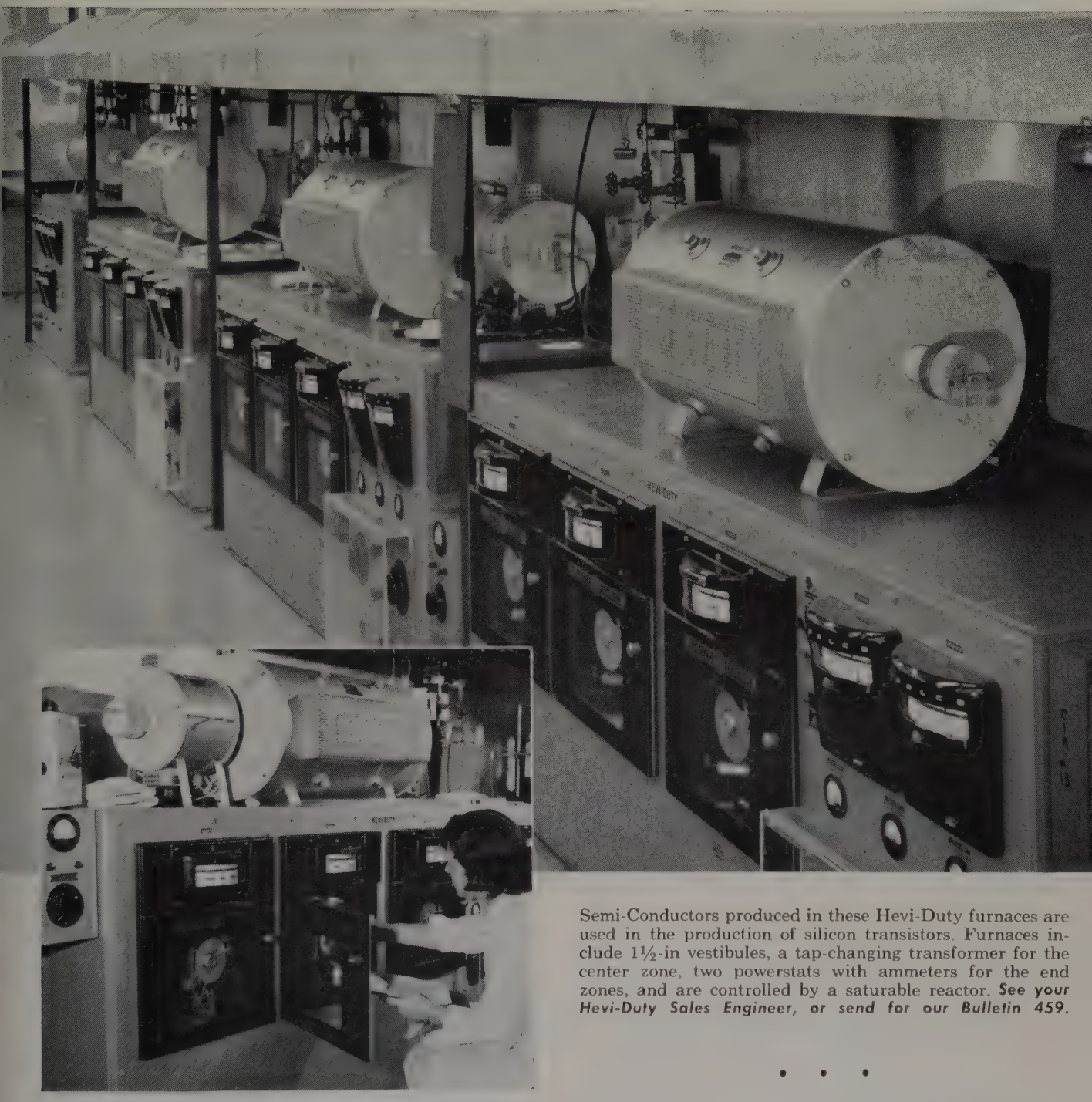
Circle No. 19 on Reader Service Card

Only Hevi-Duty Furnaces Meet Rigid Reliability Standards of Pacific Semiconductors, Inc.



Semi-Conductors produced in these Hevi-Duty furnaces are used in the production of silicon transistors. Furnaces include 1½-in vestibules, a tap-changing transformer for the center zone, two powerstats with ammeters for the end zones, and are controlled by a saturable reactor. ***See your Hevi-Duty Sales Engineer, or send for our Bulletin 459.***

• • •

To meet rigid reliability standards, Hevi-Duty globar tube-type furnaces were selected by PSI because of their tight temperature uniformity.

In the PSI Transistor Plant, at Lawndale, California, Hevi-Duty tube furnaces are used for silicon wafer diffusion at temperatures above 1200° C. During round-the-clock operation, the Hevi-Duty furnaces hold to ± 4° C over a 16-in. length within each 28-in. heating chamber . . . and to ± 1° C over a 10-in. length.

In addition to tight uniformity, Pacific Semiconductors, Inc., finds Hevi-Duty furnaces very easy to set up and load. Another important advantage is their ease of servicing. In one instance, PSI replaced a globar element while the furnace was operating at full temperature. The entire job took only 15 minutes and there were no detrimental effects on the load.

Find out how the right Hevi-Duty furnace can bring you production efficiency and laboratory accuracy.

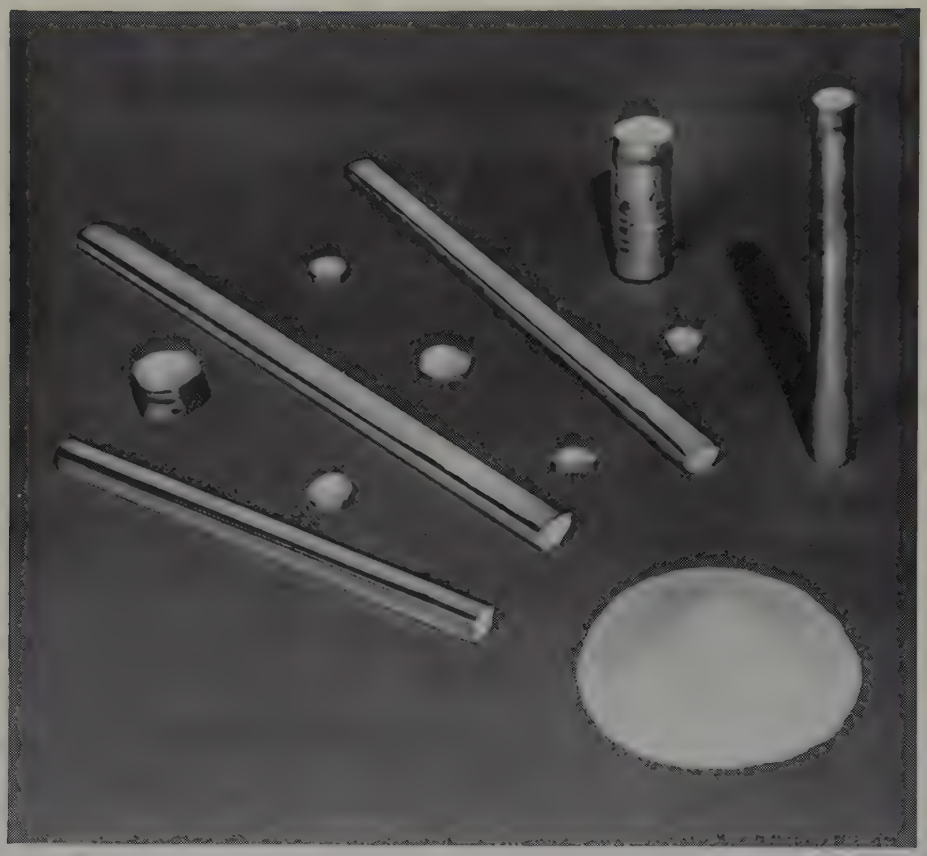
HEVI-DUTY

A DIVISION OF BPC — A Division of Basic Products Corporation

Hevi-Duty Electric Company, Watertown, Wis.

Circle No. 20 on Reader Service Card

Germanium *and other semiconductors from* **EAGLE-PICHER**



Eagle-Picher Rare Metals and Semiconductors

GERMANIUM DIOXIDE, minimum purity 99.999%.

FIRST REDUCTION GERMANIUM METAL, minimum resistivity 5 ohm-cm.

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SINGLE CRYSTAL GERMANIUM [undoped] minimum resistivity 30 ohm-cm.

SINGLE CRYSTAL GERMANIUM [doped] to customers' specified resistivity.

SPECIAL SHAPES, INTRINSIC GERMANIUM METAL, for horizontal or vertical crystal growing. Wide variety in stock, other shapes furnished to customers' specifications.

SCRAP GERMANIUM PLAN, scrap Germanium may be returned for economical reprocessing under a toll arrangement.

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GALLIUM, ultra pure.
Metallic crystals, minimum purity 99.9999%.
Metallic crystals, minimum purity 99.999%.

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Eagle-Picher, pioneer in Germanium, is an acknowledged leader in dependable production to meet the precise demands of the semiconductor industry. We offer a complete line of Germanium products and in addition, reprocess customers' *scrap Germanium* under our new low-cost toll arrangement.

FREE! An interesting, new brochure, "EAGLE - PICHER GERMANIUM" is now available. Write for your copy today.

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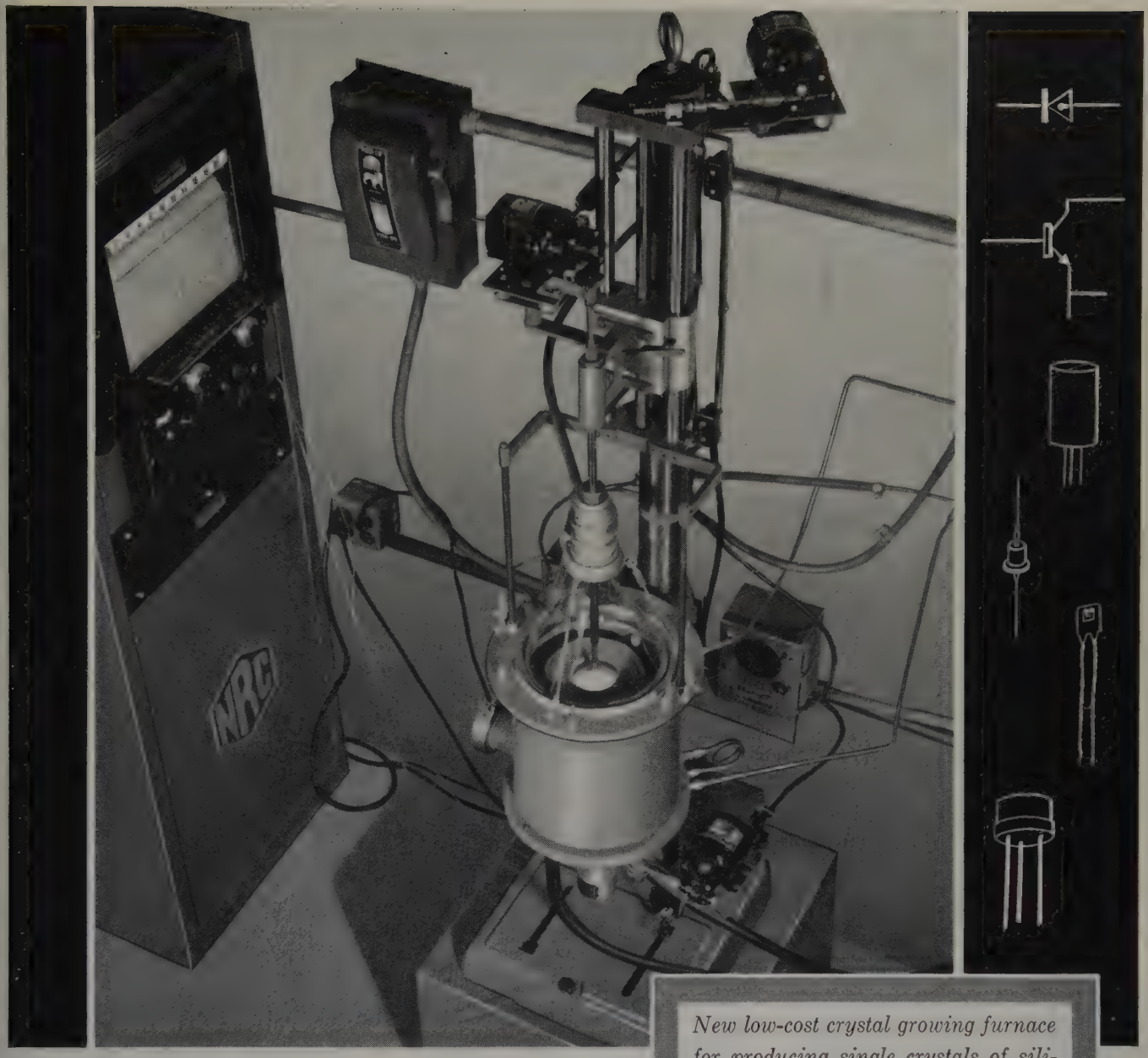

New low-cost crystal growing furnace for producing single crystals of silicon, germanium, and intermetallic compounds with reliability and consistently high quality.

NOW GROW CRYSTALS EASILY

Here's an inexpensive, packaged, production unit for making crystals for diodes, transistors, photocells, solar cells or infrared detectors. The new unit combines the three essential features needed for successful operations:

Precise temperature control of the melt — can be maintained within one-half degree.

Vibrationless operation is achieved through special shock mounts, flexible drive shafts, and precision ground screws.

Freedom from contamination is assured by leak-free fabrication and careful selection of materials used in the hot zone.

This furnace is a real money-maker. You can grow a 150 gram crystal in about three hours. It is practically foolproof to operate, easy to maintain. Because it is a resistance furnace, it has a lower initial and operating cost.

It has exceptional flexibility. Rates of seed rotation, pulling rate, crucible rotation, and crucible withdrawal in either direction are all variable and independently controlled. Diameters variable to 1¼ inch, length to 10 inches.

Investigate how much money this unit can make for you. Call or write us today for a quotation or for more detailed information describing the Model 2801-B Crystal Growing Furnace.

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Circle No. 22 on Reader Service Card

NEW *from* Penfield

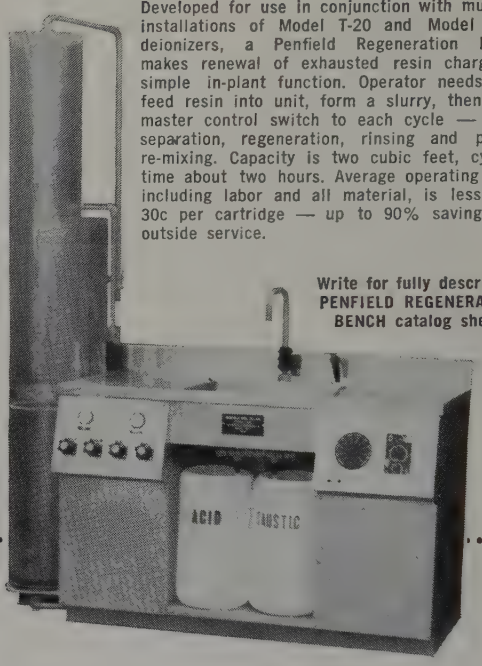
For Semiconductor and Transistor Manufacture

Pressure Cartridge Deionizer Delivers 18-22 megohm Water at Point of Use

The Penfield PM-8 is a monobed deionizer that "polishes" ultra-high purity make-up and rinse water at point of use. Unique design of top distributor and collector well permits flows up to 50 GPH at less than 4 lb. pressure drop — holds exchange efficiency at 100%. Built entirely of plastic to eliminate metallic contamination. Sump is clear, allowing visual inspection of exchange resins. Cartridge unscrews by hand for easy resin replacement. Unit also can be used as cation exchanger, anion exchanger, water softener, activated carbon filter, oxygen remover or organic scavenger.

Write for fully descriptive PENFIELD PM-8 DEIONIZER catalog sheet.

Resin Separator and Regenerator Saves up to 90% of Costs of Deionized Water



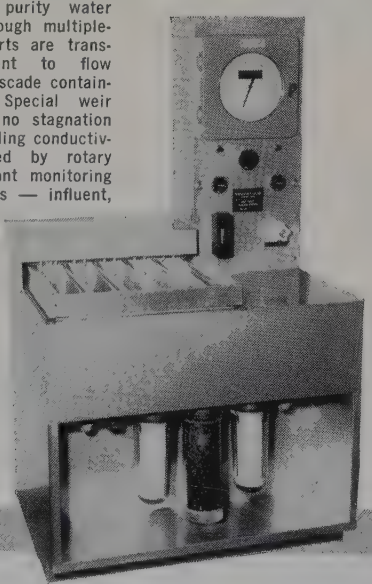
Developed for use in conjunction with multiple installations of Model T-20 and Model PM-8 deionizers, a Penfield Regeneration Bench makes renewal of exhausted resin charges a simple in-plant function. Operator needs only feed resin into unit, form a slurry, then turn master control switch to each cycle — resin separation, regeneration, rinsing and proper re-mixing. Capacity is two cubic feet, cycling time about two hours. Average operating cost, including labor and all material, is less than 30c per cartridge — up to 90% saving over outside service.

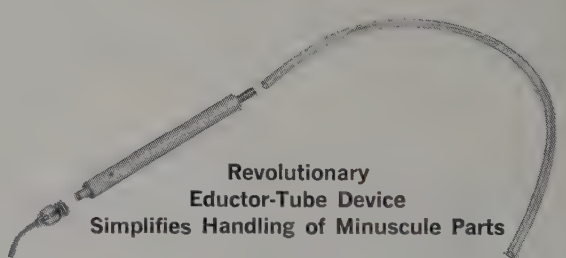
Write for fully descriptive PENFIELD REGENERATION BENCH catalog sheet.

Weir Washer "Polishes" Cascading Water to 18-22 megohms with Instant Monitoring

Integral filters and pressure-type monobed deionizers enable circulation of ultra-high purity water (18-22 megohms) through multiple-partitioned tanks. Parts are transferred counter-current to flow pattern, with each cascade containing purer water. Special weir design insures that no stagnation can occur. Direct-reading conductivity meter, controlled by rotary switch, permits instant monitoring at three check points — influent, deionizer effluent, tank effluent. Novel clip bar makes replacing heating elements simple, obviates need to empty tanks.

Write for fully descriptive PENFIELD WEIR WASHER catalog sheet.





Revolutionary Eductor-Tube Device Simplifies Handling of Minuscule Parts

New Penfield Pickup makes handling of minute particles a simpler, less costly operation. Exclusive design uses air or inert nitrogen forced through a special eductor tube at 1-2 psi. Negative pressure is created at pick-up point (where standard hypodermic needles are attached) sufficient to hold germanium, silicon or other miniscule parts. To release the held particle, operator merely finger-stops an orifice in the pickup, thus creating positive pressure. Use of Penfield Pickups eliminates all foot switches, solenoids and costly vacuum equipment — also does away with troublesome plugging problems.

Write for fully descriptive PENFIELD PICKUP catalog sheet.

Penfield

MANUFACTURING CO., INC.
19C HIGH SCHOOL AVENUE, MERIDEN, CONN.

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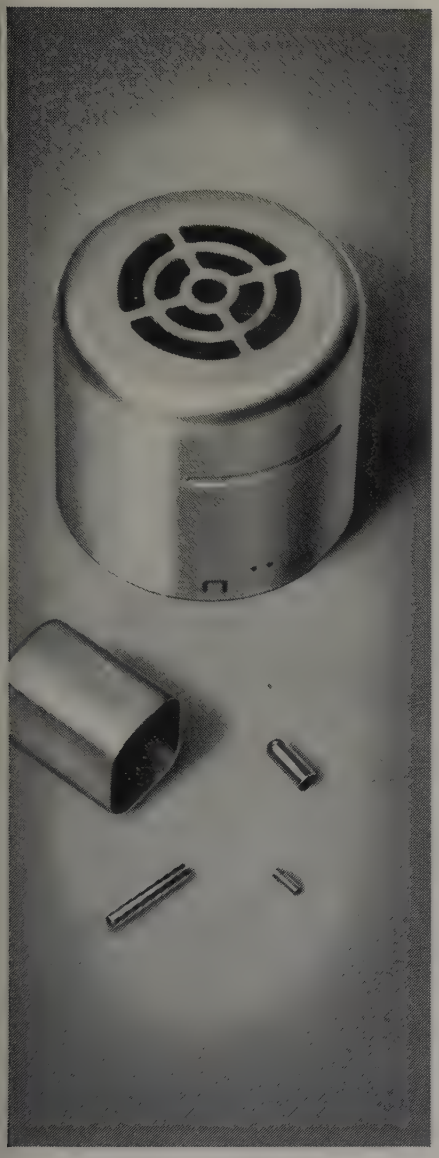
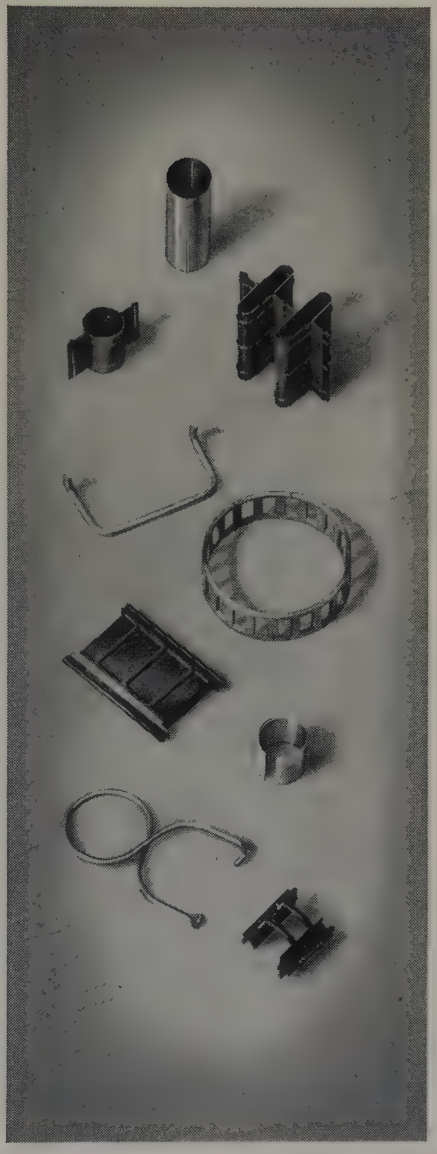
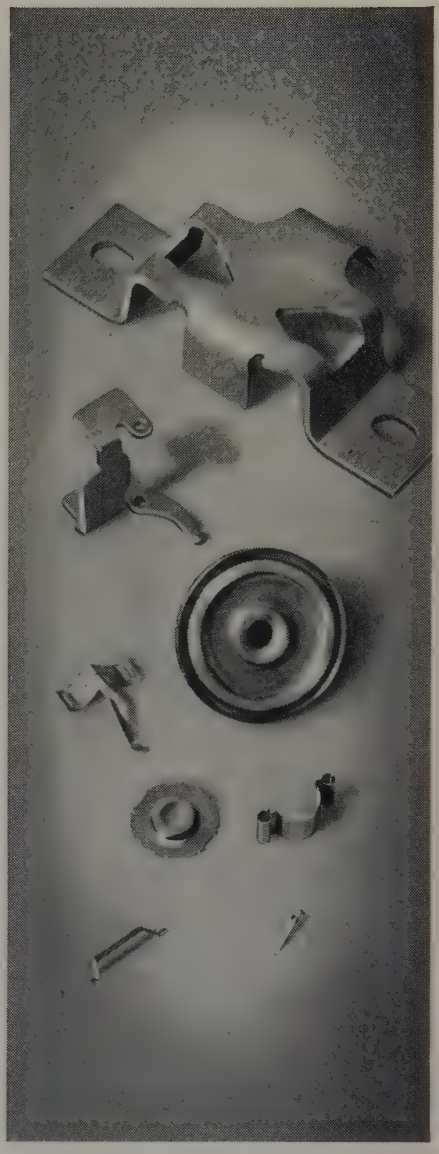
Johnson & Hoffman broadens its range



Deep-drawn parts
Up to 8 in. dia. and 4 in. deep, in material up to 1/16 in. thick.



Multi-slide parts
Wire .005 to .188 in. dia.; Strip .005 to .031 in. thick, and up to 2 in. wide.



Stampings
Up to 12 in. wide, in material up to ¼ in. thick.

Now from this one source, you can get stampings, deep-drawn parts, and multi-slide parts in a wider range of sizes than ever—but with the same close tolerances, choice of materials, and low prices. J&H has expanded its facilities by purchasing the Stamping Division of the Fred Goat Co., Inc., Brooklyn, N.Y. For a quotation on a part you need right now, simply send a drawing.

An affiliate of Superior Tube Co.

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Circle No. 24 on Reader Service Card

Some facts of supreme importance to manufacturers of semiconductor devices

How leading producers capitalize on Alpha technology to increase their yield

A number of major producers were already being supplied with aluminum spheres when they placed test orders for Alpha preforms. Result? Their percentage of usable silicon alloy diodes rose impressively. Today these companies are confirmed users of Alpha products.

In case after case, manufacturers who have switched to Alpha preforms of pure aluminum and aluminum alloys, as well as Alpha preforms of other metals and their alloys, report experiences as satisfactory as these.

It's the difference that counts!

What makes Alpha aluminum preforms so unique? *The care with which they are produced.*

As with all Alpha products, aluminum and aluminum alloy discs, spheres, washers and cut wire segments go through repeated, rigorous quality controls and counter checks. Each lot is spectrographically analyzed for adherence to your purity specifications. Alpha's spectrographic check is so accurate, it reveals the presence of unwanted elements such as magnesium and manganese even when present in quantities as minute as 1 part per 1,000,000!

In addition to this purity check, each lot is analyzed by exact quantitative techniques. This safeguards the alloy's homogeneity. It also insures that the minor constituent is present in the precise amount required.

Check and double check

Another indication of the care with which these aluminum preforms are made is the special microscopes Alpha uses to check dimensional accuracy. Spheres as large as ¼" and as small as .003" and discs and washers as thin as .0005" are checked for precise conformation to specifications.

As a further dimensional safeguard, a comparator casting an image 100 times the preform's actual size is used.

To assure freedom from surface contaminants, all Alpha preforms are processed through etching and vapor degreasing equipment. Every scintilla of foreign matter is effectively removed!

Only Alpha has it

Alpha cut segments are produced in pieces as small as .008" dia. x .016" long. Alpha engineers designed and built the machinery to do this; *only Alpha has it!*

Wire of 99.99+% purity is put through this equipment. Not only are the resulting pieces uniformly straight but the ends are cut square and parallel.

Increasing your usable output

These controls would satisfy most preforms suppliers—but not Alpha. Again and again, quality is controlled and checked by skilled technicians using the finest optical and mechanical equipment. The results reflect themselves in preforms of aluminum and other ultra high purity metals that, in case after case, increase the percentage of usable semiconductor devices.

Alpha preforms can help *your* output too. For current quotations on spheres, discs, cylinders, cubes, washers, rings and special shapes, write today. Describe alloys, dimensions and quantities wanted.

WHEN DEPENDABILITY COUNTS!

ALPHA METALS, INC.

56 Water St., Jersey City 4, N. J.

In Los Angeles, Calif.
2343 Saybrook Ave.

In Chicago, Ill.:
Alphaloy Corp.
2250 S. Lumber St.

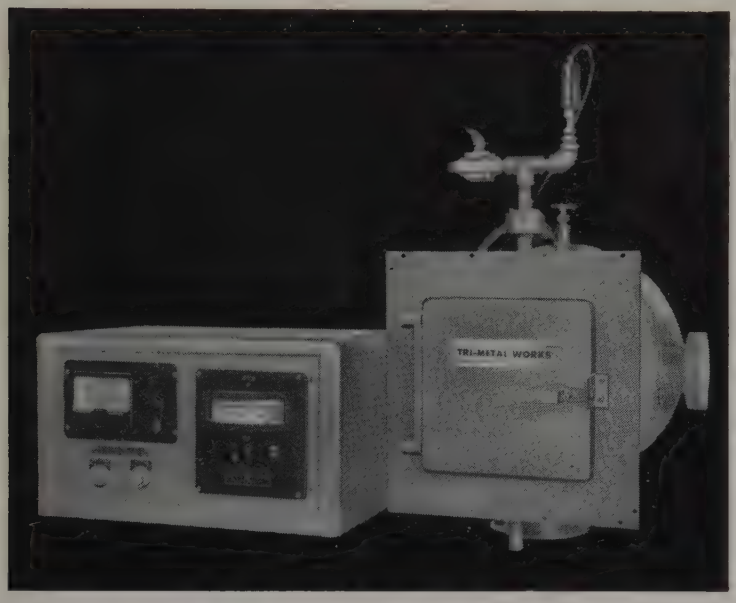
Other Alpha products: Strip with Continuous Conductive Coating, high purity dots of silver indium, cadmium, tin, lead and their alloys in shapes to your needs.

Circle No. 25 on Reader Service Card

MEET

0-8

NEW HIGHER TEMPERATURE, HIGH VACUUM OVEN



Here is Tri Metal's low-cost 0-8 oven engineers throughout the nation are talking about. This unique model consists of a suspended inner muffle surrounded by heating elements mounted on ceramic stand-off insulators. The heating elements are surrounded by a series of polished shields which reflect the radiated heat onto the muffle and thus achieve exceptional temperature uniformity. The outer shell of the oven is water cooled. No water cooling of the door is required. The low-cost Neoprene door gasket remains cool even when the oven is operating continuously at elevated temperatures.
Accepts Bench or Dry Box Mounting
Various Sizes Available.

HIGHER TEMPERATURES
Up to 800°C. (1472°F.)

BETTER UNIFORMITY
Plus or minus 3°C. (5.4°F.)

LESS MAINTENANCE
Low-Cost, Neoprene "O" ring gaskets guaranteed one year.

FASTER HEAT UP
500°C. (932°F.) in 23 minutes.

CLOSER CONTROL
I/C Thermocouple INSIDE the work zone.

HIGHER VACUUM
1×10^{-6} Torr* (mmHg) @ 500°C. (932°F.)

COOLER EXTERIOR
All surfaces cool to the touch.

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INDUSTRIAL DIVISION

Tri Metal Works is recognized as a leader in design and fabrication of high and ultra high vacuum equipment. Tri Metal Works has been engaged in the custom fabrication of high vacuum components and equipment for leading manufacturers and users since 1946.
You are invited to see a demonstration of 0-8 in our plant laboratory.
Call or write for appointment.

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*terminology recommended by Standards Committee of American Vacuum Society

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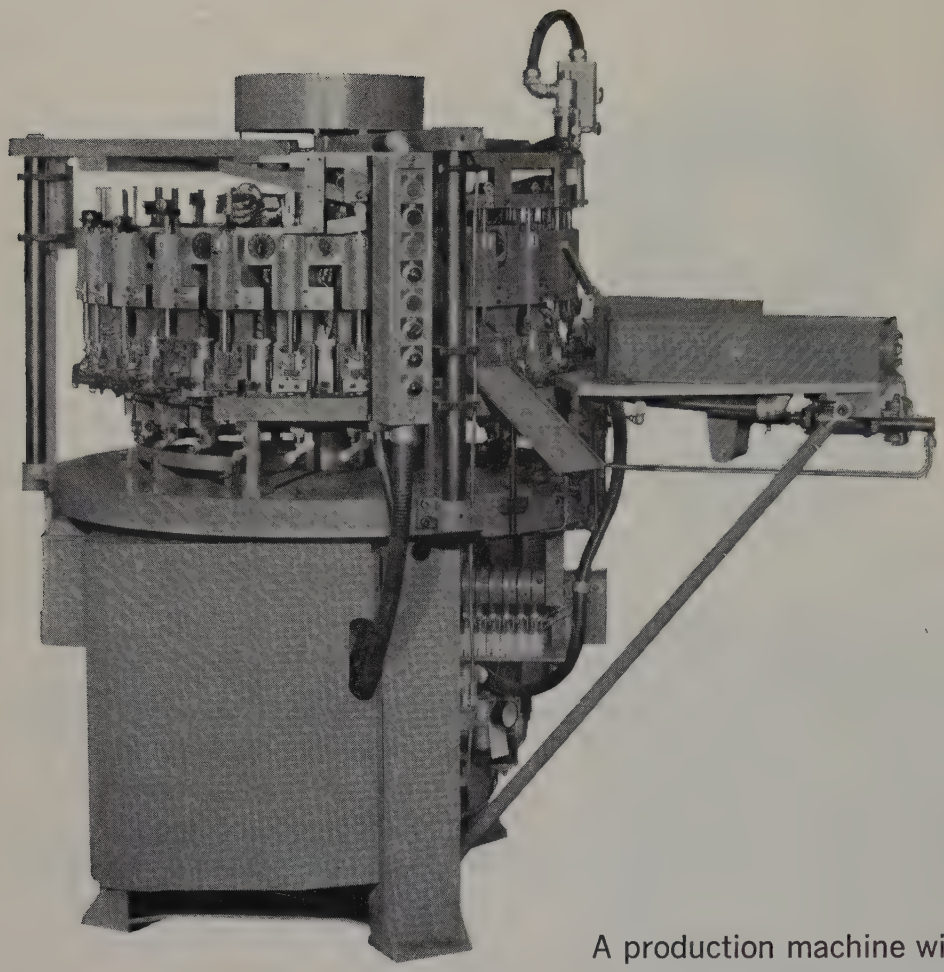

A production machine with an **EMPHASIS**
on high speed dependability
for a critical production operation
in the manufacture of CRYSTAL DIODES

AUTOMATIC
FINAL SEAL
MACHINE 3383

Built by **KAHLE** to meet the requirements of the expanding Semiconductor Industry.

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of Machinery for the Electronic Industry.

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Editorial . . .

Semiconductor Inductances and Negative Resistances

In a recent Editorial, the versatile and important properties of two-layer diodes were discussed. In particular it was pointed out that efforts to obtain high Q inductances do not appear too promising. A greater latitude of design parameters becomes available if one considers three or more layer diodes.

Ebers and Miller (*BSTJ, Sept. 1955*) have pointed out that the a-c short circuit admittance of avalanche transistors possesses negative conductance and negative susceptance in appropriate bias regions. The magnitudes of the conductance and of the susceptance generally decrease as the d-c bias current and the frequency increase. Similarly, the open circuit a-c admittance of an avalanche transistor may be made to possess negative conductance and negative susceptance if the base region is doped more than the emitter region, so that the emitter injection efficiency becomes an increasing function of the bias current.

These transistor configurations with the base-to-emitter port either short or open are actually equivalent to three layer diodes. Recently Gaertner and Schuller (*Proc. IRE, April '61*) have examined from a general point of view the necessary and sufficient conditions for the realization of negative resistances with three layer diodes. These conditions involve the current amplification factor and the collector cutoff current. For example, using common emitter parameters, a necessary condition is that the rate of change of the current amplification factor with the current should be larger than the reciprocal of the collector cutoff current.

In addition to the Ebers-Miller structure other configurations are possible. For example, in transistors with large collector resistivity a negative resistance may appear at the collector-emitter terminals, because of a modulation effect of the minority current from collector to base. This effect was explained by Early in terms of a collector multiplication factor. With appropriate design it might be utilized to realize practical negative resistance elements.

Similarly, still other structures, involving combination of collector multiplication, avalanche and doping dependent emitter efficiency may be investigated. In general the analytical expressions of the a-c admittances are unwieldy and do not lend themselves to clear cut design procedures. However, if a suitable computer and experimental program is instituted, it may be possible to arrive at an organized design procedure. This would be very useful per se, and in addition would permit the extension of the study to analogous problems of four-layer diodes.

Circuit Design Award Winner

Semiconductor Products takes pleasure in announcing that the Award for the most outstanding Semiconductor Circuit Design Article published in our magazine between April 1959 and March 1960 has been made to James J. Davidson of RCA.

The prize, consisting of a Gold Medal and $500.00, has been presented to Mr. Davidson for his article, "Transistor AC Amplifier with High Input Impedance," which appeared in the March 1960 issue of *SCP*.

James J. Davidson was born in New York, N. Y. on July 2, 1930. He received the B.S. degree in Electrical Engineering from M.I.T. in 1952. Upon graduation he joined RCA, first as a specialized trainee, then as a member of the Home Instruments Advanced Development Section in Camden, New Jersey, where he worked on transistor applications and circuit development of television receivers. In 1954, when the Television and the Radio Divisions were split, he joined the Radio Division Advanced Development Section, to work on audio and transistor circuits. Transistor noise studies were an important and continuing part of this work. In 1957 he received the I.R.E. Professional Group on Audio award for his paper "Low Noise Transistor Microphone Amplifier." In 1958 he delivered a talk on "Low-Frequency Amplifier Design" as part of the Philadelphia and the Northern New Jersey I.R.E. sections' "Transistor Applications Lecture Series." He is the author of seven published papers.

In 1960 he transferred to the RCA Victor Record Division, in Indianapolis, where he has been engaged with problems of disc and tape recording, and instrumentation for magnetic tape production. He is presently studying music, to gain a fuller understanding and appreciation of all the aspects of music reproduction.

Mr. Davidson is a member of the Audio Engineering Society and the I.R.E. and is currently working on a complete revision of the I.R.E. standard on "Methods of Measurement of Noise" (*53 I.R.E. 19 S1*).

WE'VE INCREASED YOUR FLOOR SPACE!

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Transient Response of Grounded Emitter Switching Circuits

S. C. CHAO*

The transient response of a non-saturating grounded emitter switch is analyzed in this article. The effect of collector capacitance and load resistance is taken into effect. The turn-on delay and rise time are derived assuming a ramp input voltage which is closer to the practical case than the step input normally assumed. The turn-off transient response is derived by plotting a transcendental equation. The accuracy of this analysis has been verified by experimental observations using alloy junction transistors. The results obtained may be used by circuit designers to understand and predict the response time of transistor switching circuits.

THE LARGE SIGNAL TRANSIENT RESPONSE of a junction transistor has been analyzed by Moll[1]. This analysis neglects the effect of collector capacitance. In Moll's analysis the Laplace transform technique was used to calculate the turn-on, turn-off, and hole-storage delay intervals assuming either a step voltage or a step current input. In many practical cases the effect of collector capacitance must be taken into account in order to obtain a close quantitative agreement. This has been done by Easley[2] and Bashkow[3] where either constant or varying collector capacitance was considered. In both of these analyses, however, step junction inputs were assumed.

In practical applications the input waveform can never be a step function. In the practical case the rise and fall of the input waveform more closely follows a ramp function with some rounding of the corners or it is somewhere between a ramp and an exponential function. For this reason, analyses based on a step input do not give very good quantitative agreement with experimental results. It is true, of course, that the response to any input function can be derived from a knowledge of the step response but such a derivation is tedious.

It is the purpose of this article to present a set of analytical results which enable the circuit engineer to calculate the transient response of a grounded emitter transistor switch from a knowledge of certain circuit and transistor parameters. It might seem at first glance, that the scope of the paper is rather narrow since it is concerned only with the grounded emitter configuration. However, this configuration is used almost exclusively and as such deserves detailed investigation. The transient response of grounded base and grounded collector switches could be treated in a manner similar to that which will be presented but it is felt that such treatment is not warranted.

The input excitation voltage in this treatment is assumed to have a linear rise and fall. During the transient turn-on and turn-off periods the input circuit to the transistor behaves somewhat like a high pass RC filter. The R may be associated with the equivalent base input resistance of the transistor which is non-linear and the C may, in the case of circuits using a speedup capacitor, be easily identified. In any case, with most driving circuits, if we compare the peak current supplied to the input for the case of a ramp or exponential signal, with that of a step input, it is apparent that the peak value of the transient base input current depends on the ratio of the input circuit time constant to the rise and fall time of the input excitation voltage. The peak value of the transient base input current will decrease with this ratio[4]. If we analyze, therefore, the response of the transistor to a step input excitation voltage, we will calculate a considerably shorter turn-on and turn-off delay time than will be obtained in an actual circuit which has a finite input rise and fall time. Although the exact time variation of the input waveform may be difficult to specify in practice, it is often, as has been pointed out, somewhere between a linear and an exponential function. It will be found that the first order solution (that is, the solution assuming a linear rise and fall of the input) will give close approximation to the actual case.

In this article we will treat only the non-saturated condition because in many circuit applications, saturation is avoided or at least minimized through the use of diode clamps or by selecting transistors which have a very low base stored charge.

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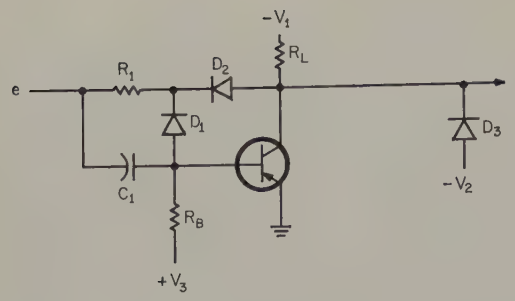

Fig. 1—A non-saturating inverter circuit.

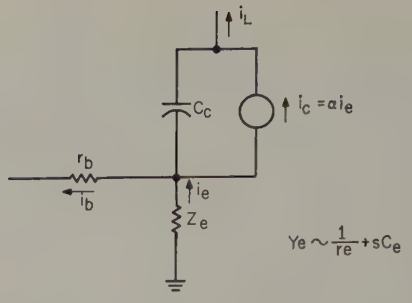

Fig. 2—Simplified equivalent circuit of a junction transistor.

Formulation of the Problem

Figure 1 shows the circuit which we will treat in this article. It is essentially a single stage, Class C amplifier. In pulse and digital applications, it is generally referred to as an "inverter" since an up-going pulse applied to the input will provide a down-going pulse at the output. The transistor is operated as a switch, i.e., in the steady-state it is either in cutoff or in full conduction. In this circuit, saturation (and, hence, minority carrier storage delay) is prevented by a diode clamping technique. Diode D_1 is a silicon diode which has a larger voltage drop when conducting than the germanium diode, D_2. This means that the collector will have a potential which is a few tenths of a volt lower than the base (assuming a *pnp* transistor) when the transistor is in full conduction. Diode D_3 is a "catching" diode which is used to improve fall time. It also maintains the collector voltage at a constant level when the transistor is off in spite of variations in the load. Bias current is provided to the transistor from supply V_3 through resistor, R_B, for the purpose of temperature compensation since the collector saturation current, I_{co}, is an increasing function of temperature. Since circuit saturation is prevented in this, the transistor, when on, is always operating in the active region, and hence a single equivalent circuit which represents the active region can be used for the calculation of the overall circuit response. *Fig. 2* shows an often used simplified T equivalent circuit and a junction transistor. In this equivalent circuit the collector resistance, r_c, is neglected. It is also assumed that during the transient the emitter impedance is, for all practical purposes, a short circuit. This is justified because the emitter resistance, r_e, is much smaller than the bases resistance, r_b, and the emitter transition capacity, C_e is generally much larger than the coupling capacitor C_1. It can be demonstrated that with such inequalities the emitter impedance can be neglected. With this approximation, the input impedance of the transistor is then assumed, to be equal to r_B. When the transistor is cut off we will assume that the input impedance is infinity. The collector capacitance, C_c, is assumed in this analysis to be constant rather than to vary with collector voltage. It will be shown later that in the grounded emitter configuration the collector capacitance is modified by the term $1/(1-\alpha)$. The collector saturation current, I_{co}, is considered to be small and is therefore neglected in all of these calculations. The variation of current gain with emitter current and collector voltage is also ignored.

It is obvious that in the treatment of this problem, any assumption or approximation will directly effect the accuracy of the results. On the other hand, a more complicated model makes the analysis extremely difficult and, therefore, not as useful from an engineering point of view. This simple equivalent circuit, together with the stated assumptions, has proved in practice to give analytical results that agree to within 10 or 15% of observed experimental results. It is, therefore, felt that this simple equivalent circuit has sufficient accuracy to make it a useful engineering tool.

Turn-On Delay and Rise Time

In the equivalent circuit of *Fig. 3* the transistor is assumed to be driven with a ramp input voltage $e(t)$ varying from 0 to $-E$ volts. The fall time of the input voltage is τ_1. The turn-on delay interval consists of two parts. The first is the delay due to the bias circuit and the second is the delay due to the collector clamp circuit. (The collector voltage will not start to change until diode D_3 turns off). These two parts of the delay interval will be calculated separately.

Bias Delay

Since in this circuit the base voltage is initially positive and equal to $V_3R_1/(R_1+R_B)$, the transistor is cut off and its input impedance may be assumed to be very high. The time required for the base voltage, V_b, to become equal to zero is the portion of the turn-on delay which is assignable to the bias circuit. For this portion of the turn-on delay, only the input network need be considered. The Laplace transform of V_b is given by:

$$V_b(s) = V_3 \frac{R_{11}}{R_B} \frac{1}{s} - \frac{E}{\tau_1} \frac{R_{11}}{R_1} \frac{1}{s^2} \frac{1+C_1R_1s}{1+C_1R_{11}s} \qquad (1)$$

where

$$R_{11} \triangleq \frac{R_1 R_B}{R_1 + R_B}$$

The inverse transform of V_b, as a function of time, is given by:

$$v_b(t) = \frac{V_3 R_{11}}{R_B} - \frac{E R_{11}}{\tau_1}\left[C_1\left(1-\frac{R_{11}}{R_1}\right)+\frac{t}{R_1}-C_1\left(1-\frac{R_{11}}{R_1}\right)e^{-\frac{t}{C_1 R_{11}}}\right]. \quad (2)$$

The bias delay portion of the turn-on delay time can be obtained by solving Eq. (2) for T with the lefthand side of the equation set to zero. In order to simplify the solution, the exponential term can be approximated by using the first two terms of the series. If we do this, Eq. (2) becomes:

$$v_b(t) \approx \frac{V_3 R_1}{R_1 + R_B} - \frac{E}{\tau_1} t \quad (3)$$

Solving this simplified equation, the bias delay time, T_1 is given by:

$$T_1 \approx \frac{V_3}{E} \frac{R_1}{R_1 + R_B} \tau_1 \quad (4)$$

Note that the result obtained in Eq. (4) is the same result which one would have obtained if it was assumed that resistor R_1 were completely bypassed by capacitor, C_1 during the transient interval.

Delay Due to Collector Clamping

When the transistor starts conducting its input impedance becomes very low. In most cases it will be much smaller than R_1 or R_B. The transient base current, i_b, may be calculated from a series circuit consisting of C_1 and r_b if the origin of the input voltage is shifted to $-V_3R_{11}/R_B,T_1$. During this portion of the delay time the Laplace transform of the base current is given by:

$$I_b(s) = -\frac{E}{\tau_1 r_b} \frac{\left[1 - e^{-\tau_1\left(1-\frac{V_3 R_{11}}{E R}\right)s}\right]}{s\left(s+\frac{1}{C_1 r_b}\right)} \quad (5)$$

Let us assume that α is given by:

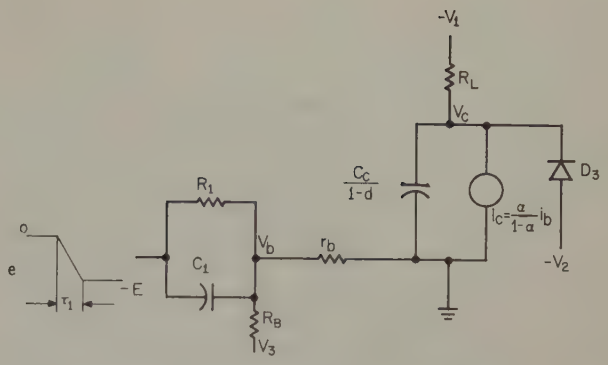

Fig. 3—Equivalent circuit used to calculate turn-on delay.

$$\alpha = \frac{\alpha_0 \omega_\alpha}{s + \omega_\alpha},$$

where α_0 is the low frequency value of the current and ω_α represents the angular alpha cutoff frequency. The collector current generator of *Fig. 3* is then given (in the s domain) by Eq. 6 below.

The inverse transform of Eq. (6) can be found readily; however, only the first part ($t<\tau_1'$) is of interest to us. This is given by:

$$\frac{i_c(t)}{-\frac{E C_1}{\tau_1}\beta_0} = 1 - \frac{e^{-\omega_\beta t}}{1 - C_1 r_b \omega_\beta} + \frac{C_1 r_b \omega_\beta}{1 - C_1 r_b \omega_\beta} e^{-\frac{t}{C_1 r_b}} \quad (7)$$

In many practical designs $C_1 r_b \omega_\beta << 1$.

Also $e^{-\omega_\beta t}$ varies slowly while $e^{-\frac{t}{C_1 r_b}}$ falls off rather fast after the beginning of the transient, hence, the following first order approximation may be used to solve Eq. (7).

$$i_c(t) \sim \frac{-E C_1}{\tau_1}\beta_0 (1 - e^{-\omega_\beta t}) \sim -\frac{E C_1}{\tau_1}\alpha_0 \omega_\alpha t \quad (8)$$

It will be observed from Eq. (8) that the transient collector current depends primarily on the alpha cutoff frequency of the transistor and is independent of the grounded emitter current gain, β_0. It should, of course, be realized that a certain minimum beta is required in order to establish the static conditions

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$$I_c(s) = I_b(s) \frac{\alpha_0 \omega_\alpha}{s + \omega_\beta}$$

$$I_c(s) = -\frac{E C_1}{\tau_1}\omega_\alpha \beta_0 \left[\frac{1}{s} - \frac{1}{(1 - C_1 r_b \omega_\beta)(s + \omega_\beta)} + \frac{C_1 r_b \omega_\beta}{(1 - C_1 r_b \omega_\beta)\left(s + \frac{1}{C_1 r_b}\right)}\right](1 - e^{-\tau_1' s}) \quad (6)$$

where

$$\omega_\beta \triangleq \omega_\alpha (1 - \alpha_0),$$

$$\beta_0 \triangleq \frac{\alpha_0}{1 - \alpha_0},$$

$$\tau_1' = \tau_1\left(1 - \frac{V_3}{E}\frac{R_{11}}{R_B}\right).$$

of the switch. It should be understood that a very large transient base current flows while the transistor is turning on. This transient base current is many times larger than the steady-state base current. While the collector current builds up almost linearly except for a slower rate at the beginning of the transient, both currents would reach their peak values respectively at $t = \tau'_1$ if the collector current were not limited by the external load. The portion of the turn-on delay interval due to the collector clamp action will be over when the collector current becomes equal to the clamp current, $(V_1 - V_2)/R_L$. Thus, we may solve for this portion of the delay interval by equating the lefthand side of Eq. (8) to this quantity. If we then calculate T_2, this portion of the delay interval is given by:

$$T_2 \sim \frac{V_1 - V_2}{E} \frac{\tau_1}{C_1 R_L} \frac{1}{\alpha_0 \omega_\alpha} \tag{9}$$

The total turn-on delay time is the sum of Eq. (4) and Eq. (9).

Rise Time

The rise time may be calculated using the equivalent circuit shown in *Fig. 4*. In this circuit the capacitive term $C_c/(1-\alpha)$ of *Fig. 3* has been synthesized into three elements. Because of the relatively large value of $\beta_o C_c$ it is reasonable to assume that this capacitor will not be appreciably charged during the transient interval. In other words, for the conditions shown in *Fig. 4*, we may assume that this capacitor will stay charged to the constant potential $-V_2$. Another way to justify this is to realize that the time constant of the series *RC* branch is the reciprocal of ω_β which, in general, is a long time compared to the rise time interval of the circuit. The exact Laplace transform of the collector voltage V_c, of the equivalent circuit of *Fig. 4* is:

$$V_c(s)\left[\frac{s+\omega_\alpha}{s+\omega_\beta} C_c s + \frac{1}{R_L}\right]$$

$$= I_c(s) - V_2 C_2 \frac{s+\omega_\alpha}{s+\omega_\beta} - \frac{V_2}{R_L s}$$

$$= \frac{E C_1 \alpha_0 \omega_\alpha}{\tau_1} \frac{1}{s^2} - V_2 C_c \frac{s+\omega_\alpha}{s+\omega_\beta} - \frac{V_2}{R_L s}. \tag{10}$$

Using the assumption that the effect of the capacitor, $\beta_o C_c$ is negligible, we can simplify Eq. (10) to:

$$V_c(s) \approx -\frac{A}{s} + \frac{I_{ch}\alpha_0\omega_\alpha}{G s^2} + (A - V_2)\frac{1}{s + G/C_c}, \tag{11}$$

where

$$I_{ch} = \frac{E C_1}{\tau_1}, \qquad G = \frac{1}{R_L} + \alpha_0 \omega_\alpha C_c,$$

$$A \triangleq \frac{1}{G}\left[\frac{I_{ch}\omega_\alpha \alpha_0 C_c}{G} + V_2(G)\right]$$

If we now take the inverse transform of the function,

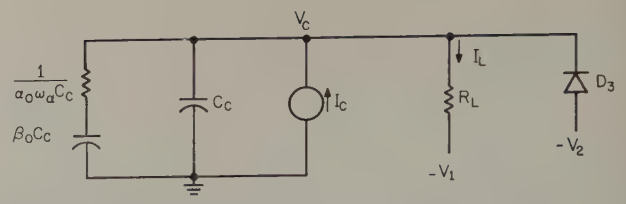

Fig. 4—Equivalent circuit used to calculate rise time.

we have the collector voltage as a function of time given by:

$$v_c(t) \approx -A + \frac{1}{G}(I_{ch}\alpha_0\omega_\alpha)t + (A - V_2)e^{-\frac{Gt}{C_c}}. \tag{12}$$

The rise time interval will be finished when the collector voltage equals zero. In the actual circuit given in *Fig. 1* the collector is clamped to stay out of saturation and, hence, the rise time interval is actually over when the collector voltage has attained a voltage which is a few tenths of a volt negative. However, the calculation is made easier by assuming the rise time interval is over when the collector voltage is equal to zero and the error introduced is negligible. Since the last term in Eq. (12) falls off very rapidly with time we may neglect it and may then solve for the rise time by equating the first two terms of Eq. (12) to zero. The solution which results is:

$$T_3 \approx \frac{AG}{I_{ch}\alpha_0\omega_\alpha} = \frac{C_c R_L}{1 + \alpha_0\omega_\alpha C_c R_L} + \tau_1 \frac{V_2 C_c}{E C_1}\left(1 + \frac{1}{\alpha_0\omega_\alpha C_1 R_L}\right) \tag{13}$$

Sample Calculation

In order to verify the results of this section a number of transistors were observed in the circuit of *Fig. 1* with $V_1 = 30$ *v*, $V_2 = 10$ *v*, and $V_s = 30$ *v*. Resistor R_1 was made equal to 10K, $R_B = 150$K, $R_L = 3.9$K and $C_1 = 120$ *pf*. The driving waveform was a 10 *v* pulse with a rise time of .25 μs. The transistors were alloy junction units having an alpha cutoff frequency of approximately 5 *mc*, $\beta > 30$ and C_c of approximately 10 *pf*. The calculated times for this circuit with such transistors were $T_1 = 0.5$ μs, $T_2 = 0.035$ μs and $T_3 = 0.06$ μs. The observation showed that the total turn-on delay interval was approximately .1 μs and the rise time interval was approximately .08 μs. In view of all of the approximations made in the analysis and the fact that the input voltage could not be made to be exactly a ramp function, the experimental results may be considered to be in close agreement with the calculations.

Fall Time

The back-clamping diodes, D_1 and D_2, prevent the transistor from going into saturation. Hence, the circuit of *Fig. 1* will exhibit no hole storage delay time. A small recovery delay due to diode D_2 of the order

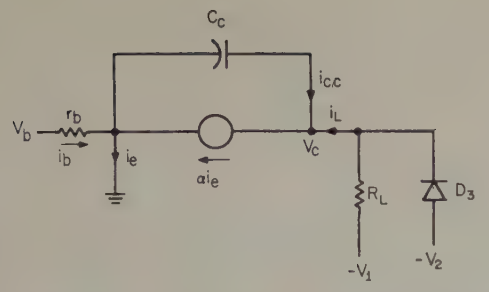

Fig. 5—Equivalent circuit used to calculate emitter current cut-off.

of 10 or 20 mμsec should be expected. This may introduce a small overshoot in the collector voltage, but this effect is neglected in the following calculations. The turn-off transient is complicated by the fact that, due to the large reverse hase current flowing during the turn-off interval, the emitter junction cuts off first while the collector current falls off in an approximately exponential manner after the emitter current has reached zero. In our analysis the reverse base current is first calculated and then the emitter current is calculated. The time required for the total emitter current to reach zero is next obtained. The collector current, which is given by the emitter current multiplied by the complex alpha, is next obtained and finally the form of the collector voltage equation is determined and the fall time is calculated.

Emitter Current

It is assumed that initially the transistor is at full conduction. The collector current is given approximately as V_1/R_L, the emitter current is $V_1/\alpha_o R_L$ and the base current is $V_1/\beta_o R_L$. Since the initial base current is much smaller than the transient base current during the fall interval it can and will be neglected without introducing appreciable error. For a ramp function input voltage which rises from —E to 0 in time τ_2, the base current is given by:

$$I_b(s) = \frac{E\,C_1}{\tau_2}\left(\frac{1}{s} - \frac{1}{s + \frac{1}{r_b\,C_1}}\right)(1 - e^{-\tau_2 s}) \qquad (14)$$

In this equation, R_1 and R_B of the circuit of *Fig. 1* are assumed to be open or infinite as far as transients are concerned. In Eq. (14) only the time interval between zero and τ_2 is of interest because the base current reaches its peak at $T = \tau_2$, and the emitter current must vanish before this time. The transient component of the emitter current may be calculated using the equivalent circuit of *Fig. 5*. Solving nodal equations, we have:

$$I_b(s) = I_e(s)\,\frac{(1-\alpha) + C_c\,R_L\,s}{1 + C_c\,R_L\,s}. \qquad (15)$$

Substituting for complex alpha and for I_b from Eq. (14) we have Eq. 16 below.

In practical applications ω_s can be neglected because of its small value since α_o is generally very close to unity. With this assumption, Eq. (16) can be handled analytically and gives rise to Eq. 17 below.

We can make a further simplification in Eq. (17) by noting that the linear term dominates in this equation. For example, consider the numerical example that was used to calculate the rise time previously. Assuming that r_b is approximately 500 ohms, we obtain:

$$\frac{i_e(t)}{I'_{ch}} \approx .07 + 13.6\,t - .14\,e^{-55\,t} + .07\,e^{-20\,t}$$

where t is in microseconds. Note that the linear term dominates all of the other terms after a few millimicroseconds. Therefore, for practical purposes we may considerably simplify Eq. (17). Taking the inverse transform we have the result that:

$$i_e(t) \approx \frac{I'_{ch}\,\alpha_0\,\omega_\alpha}{1 + C_c\,R_L\,\omega_\alpha}\,t. \qquad (18)$$

Since the initial emitter current was equal to $V_1/\alpha_o R_L$, we may determine the time that it takes the emitter current to reach zero by setting Eq. (18) to this value. If we do this we have the time taken for the emitter current to reach zero as:

$$T_4 \approx \frac{V_1\,\tau_2\,(1 + \omega_\alpha\,C_c\,R_L)}{E\,\alpha_0^2\,\omega_\alpha\,C_1\,R_L} \qquad (19)$$

$$I_e(s) = \left[1 + \frac{\alpha_0\,\omega_\alpha}{C_c\,R_L\,s^2 + (1 + C_c\,R_L\,\omega_\alpha)\,s + \omega_\alpha}\right]\frac{E\,C_1}{\tau_2}\left(\frac{1}{s} - \frac{1}{s + \frac{1}{r_b\,C_1}}\right). \qquad (16)$$

$$\frac{I_e(s)}{I'_{ch}} \approx \frac{1}{s}\left[1 - \frac{\alpha_0\,\omega_\alpha}{C_c\,R_L\,\omega'^2_\alpha} - \frac{\alpha_0\,\omega_\alpha\,r_b\,C_1}{\omega'_\alpha\,C_c\,R_L}\right] + \frac{1}{s^2}\,\frac{\alpha_0\,\omega_\alpha}{\omega'_\alpha\,C_c\,R_L}$$

$$+ \frac{\alpha_0\,\omega_\alpha}{C_c\,R_L\,\omega'_\alpha\,(s + \omega'_\alpha)}\left(\frac{1}{\omega'_\alpha} + \frac{r_b\,C_1}{1 - r_b\,C_1\,\omega'_\alpha}\right) - \frac{1}{s + \frac{1}{r_b\,C_1}}\left[1 + \frac{\alpha_0\,\omega_\alpha\,r_b^2\,C_1^2}{C_c\,R_L\,(1 - r_b\,C_1\,\omega'_\alpha)}\right] \qquad (17)$$

where $\omega'_\alpha = \omega_\alpha + \frac{1}{C_c\,R_L}$ and $I'_{ch} \triangleq \frac{E\,C_1}{\tau_2}$.

After this time the emitter current will remain equal to zero. Thus, considering only the transient part of the emitter current the complete equation for the transient portion of the emitter current is given by:

$$i_e(t) \approx I'_{ch} \frac{\alpha_0 \omega_\alpha}{1 + \omega_\alpha C_c R_L} t, \quad 0 < t < T_4$$

$$i_e(t) \approx \frac{V_1}{\alpha_0 R_L}, \quad t > T_4 \tag{20}$$

Taking the Laplace transform of Eq. 20 we have the transformed emitter current as:

$$I_e(s) \approx \frac{I'_{ch} \alpha_0 \omega_\alpha}{1 + \omega_\alpha C_c R_L} \frac{1}{s^2} (1 - e^{-T_4 s}) \tag{21}$$

The Collector Current

The transient collector current is related to the transient emitter current by the complex alpha. Thus, we may write the Laplace transform of the transient collector current as:

$$I_c(s) = \frac{\alpha_0 \omega_\alpha}{s + \omega_\alpha} I_e(s)$$

$$= I'_{ch} \frac{\alpha^2_0}{(1+\omega_\alpha C_c R_L)} \left(\frac{\omega_\alpha}{s^2} - \frac{1}{s} + \frac{1}{s+\omega_\alpha} \right) (1 - e^{-T_4 s}). \tag{22}$$

Taking the inverse transform of this equation we have the transient solution for the collector current as shown in Eq. 23 below, where $u(t)$ is a step function which is unity for $t>0$ and zero for $t<0$.

From Eq. (23) we see that the collector current starts to change slowly with an initial slope of zero. As time goes on it builds up almost linearly until $t = T_4$. It then tapers off and approaches its asymptotic value V_1/R_L exponentially.

Fall Time

The fall time is defined as the time for the collector voltage to fall from its initial value near zero to the clamping voltage, $-V_2$. Depending upon the value of V_2 this time can be either less than or greater than T_4. Another way of looking at this is that the collector voltage transient may be over before the emitter junction cuts off. If this is the case, we need not concern ourselves about what happens after T_4. However, it is more instructive to consider the general case where the collector voltage reaches $-V_2$ at a time after T_4.

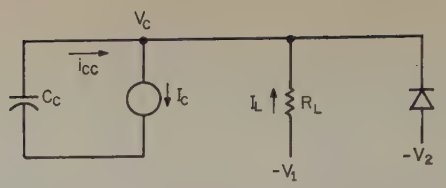

Fig. 6—Equivalent circuit used to calculate collector voltage fall time.

Using the assumption that the input impedance of the transistor is small when it is conducting and infinite when it is cut-off, the collector voltage may be calculated from the equivalent circuit shown in *Fig. 6* where only the transient parts of the currents and voltages are considered. The transient solution for the collector current was derived in Eq. (23). Using the circuit of *Fig. 6* the transient collector voltage may be expressed by Eq. 24 below.

The fall time may be obtained by taking the inverse transform of Eq. (24) and equating it to V_2. It is quite difficult to obtain the exact solution to this equation and, therefore, it is recommended that a graphical solution be used.

Sample Calculation

Let us calculate the fall time using the circuit of *Fig. 1* and the values given previously with the exception that we now assume that the input voltage goes from —10 v to 0 linearly, in a time τ_2 equal to 0.15 μs. For this case, T_4 is calculated as .082 μs. A graphical solution for the collector voltage for this particular case is shown in *Fig. 7*. This solution shows that the time taken to reach V_2 is approximately .09 μs. Experimental results show the fall time to be very close to this value.

Conclusion

The transient response of the grounded emitter transistor switch has been analyzed. Turn-on delay, rise and fall times are expressed explicitly in terms of circuit and transistor parameters or are reduced to a final form which can be used for plotting. Despite the many assumptions which were made in the treatment, the results show good agreement with experimental observations. A ramp rather than an exponential input was chosen because it was felt that the

$$i_c(t) = \frac{I'_{ch} \alpha_0^2}{1 + \omega_\alpha C_c R_L} \left\{ (\omega_\alpha t - 1 + e^{-\omega_\alpha t}) + u(t - T_4) [1 - \omega_\alpha (t - T_4) - e^{-\omega_\alpha (t - T_4)}] \right\} \tag{23}$$

$$V_c(s) = \frac{I_c(s)}{C_c s + 1/R_L}$$

$$= \frac{\alpha_0^2 I'_{ch} R_L}{1 + \omega_\alpha C_c R_L} (1 - e^{-T_4 s}) \left[-\frac{1 + \omega_\alpha C_c R_L}{s} + \frac{\omega_\alpha}{s^2} + \frac{1}{(1 - \omega_\alpha C_c R_L)(s + \omega_\alpha)} - \frac{(C_c R_L \omega_\alpha)^2}{(1 - \omega_\alpha C_c R_L)} \frac{1}{\left(s + \frac{1}{R_L C_c}\right)} \right] \tag{24}$$

ramp function is most applicable to pulse circuitry. Suitable interpretation of τ_1 and τ_2 can lead to a reasonable quantitative analysis of the transient response when the input waveform approaches an exponential form.

In this article, alloy junction transistors with alpha cutoff frequencies ranging up to 20 *mc* were considered. These transistors are widely used in pulse and digital computer circuits at pulse rates from a few hundred kilocycles to 1 or 2 megacycles. In examining the results, some general remarks can be made.

a. During the turn-on interval the sum of times T_1, T_2 and T_3 is generally less than τ_1.
b. The fall time can be either larger or smaller than τ_2 depending on the value of the clamping voltage, V_2.
c. The clamping voltage, V_2 introduces a turn-on delay increment T_2 but reduces the fall time. Thus, a circuit design compromise has to be made between the two effects.
d. α_o rather than β_o is involved in all expressions, which substantiates the statement that the grounded emitter current gain of the transistor does not influence the response time of the transistor.
e. The alpha cutoff frequency ω_α is the only dominant transistor parameter entering in the final results.

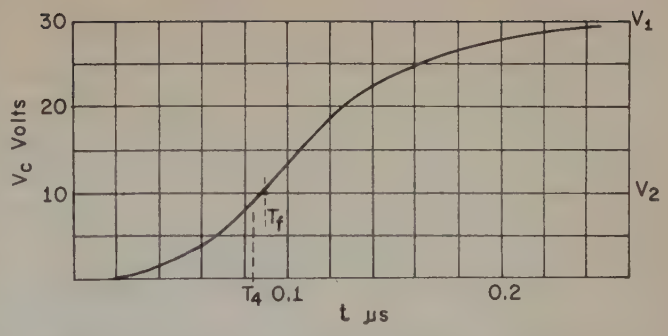

Fig. 7—Graphical method for determining fall time.

Although steady-state operation has not been treated in this article, the circuit designer must, of course, consider it also. The transient analysis made herein may be used as a guide in choosing circuit parameters which effect the transient response. The steady-state performance must serve as a guide for choosing the remaining circuit parameters.

References

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2) J. W. Easley, "Effect of Collector Capacitance on the Transient Response of Junction Transistors," *IRE Trans. PGED*, Jan. 1957, pp 6-14.
3) T. R. Bashkow, "Effect of Nonlinear Collector Capacitance on Collector Rise Time," *IRE Trans. PGED*, Oct. 1956, pp 167-172.
4) Millman and Taub, "Pulse and Digital Circuits," McGraw-Hill 1956, Chapter 2.

A Low-Cost Pre-Set Transistorized Counter

R. R. PAINTER* R. A. CHRISTENSEN*

This article describes the design and construction of a low-cost, general-purpose, transistorized counter which accepts incoming information in the form of mechanical displacements from a microswitch, light-intensity variations from a photocell, or electrical signals. The two-decade counter may be pre-set to count numbers up to 100 at counting rates up to 10,000 per second. Numbers greater than 100 can be counted by the use of additional decades having no input circuit.

COUNTING IS ACCOMPLISHED in this system by the use of four binary stages per decade with appropriate feedback to produce a decimal count. Consequently, for numbers less than 10^n, some type of resetting circuit is necessary.

The resetting circuit employed in the counter shown in *Fig. 1* sets the counter to the complement of the number to be counted. For example, if the number to be counted is 3, the decade is pre-set to the 7th state so that 3 input pulses set the decade to the 10th state and produce the desired output. Because this counter uses more than one decade, it is necessary that the reset circuit be disabled during the counting period. For example, the procedure

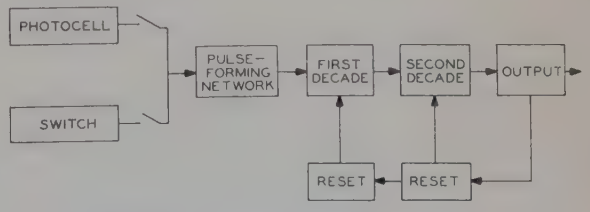

Fig. 1—Over-all block diagram.

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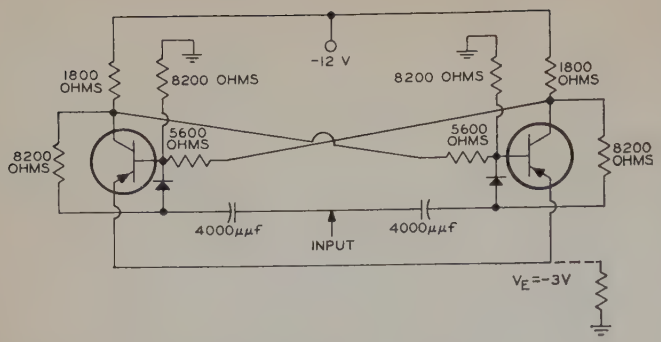

Fig. 2—Flip-flop circuit.

used to count the number 33, which requires two decades, is as follows. The states of both decades are pre-set to the complement of the number to be counted—the "units" decade to the 7th state and the "tens" decade to the 6th state. After three input pulses, the "units" decade transmits a pulse to the "tens" decade. Because the reset circuit is disabled, the "units" decade now requires ten input pulses to produce additional outputs. Therefore, 33 input pulses are required to trigger the "tens" decade to the 10th state and produce the desired output.

The output stage of the counter is a bistable stage capable of driving a relay. It is also possible to use a monostable output stage, in which case the counter will return to the counting mode after some predetermined interval of time.

A Schmitt circuit driven by an amplified signal from a photocell, a microswitch, or an electrical signal, provides the input signal to the decades. A block diagram of the over-all system is shown in *Fig. 1.*

Bistable Design

The bistable stages are of the Eccles-Jordan type, as shown in *Fig. 2.*

The following conditions were considered necessary for *d-c* stability:

(1) The "on" transistor must be saturated.
(2) The "off" transistor must be reverse-biased by some positive voltage.
(3) The collector current of the "on" transistor must always be less than its maximum specified collector current.

On the basis of these conditions, a complete general solution for d-c stability was obtained.[1] This solution permits the computation of nominal values for all components for any given combination of supply voltage, collector current, and transistor characteristics.

A supply voltage of —12 volts and a nominal collector current of 5 milliamperes were chosen. To provide a reverse-bias voltage that would be positive with respect to the emitter (condition 2 above), without the use of more than one power supply in the over-all system, it was necessary to design the bistable stages with a common-emitter resistor. Since a constant current always flows through this resistor, the emitters are assumed to always be at the same negative voltage with respect to ground. A nominal value of —3 volts across the emitter resistor was selected and values for the collector resistor (R_c) and emitter resistor (R_e) were computed.

When the collector current is known, it is possible to calculate the R_b and R_f values necessary for proper operation even though all components and parameters have degraded to their worst possible values. In this circuit, a tolerance of 10 percent was assumed for all resistors and for the power supply. The "end-of-life" values for the beta, V_{CE} and V_{BE} of the transistors, together with the "end-of-life" 55° C I_{BO}, were used in the calculations.

It is now possible to obtain an equation containing R_b and R_f or the "on" condition which satisfies conditions 1 and 3. Similarly, it is possible to derive an equation containing R_b and R_f which satisfies condition 2. These equations may be solved simultaneously for R_b and R_f.

The bistable stages are triggered by means of a positive-going signal which is gated to the base of the "on" transistor. Since the trigger turns the "on" transistor "off," the value of the charge stored in the capacitor of the triggering circuit must be larger than the maximum charge stored in the transistor. For medium-to-high-speed switching, the value of this capacitor plays an important part in determining the maximum repetition rate of the counter (because of the *R-C* time constants involved). The maximum value of the capacitor was not an important consideration, since this counter is a low-speed type, and was chosen slightly larger than necessary to insure reliable triggering.

Decade Design

Each decade employs feedback to obtain a decimal count from the normal 16-count binary. The feedback merely cancels 6 of the 16 possible binary states by resetting the second and third binary stages to the "one" state when the fourth stage is triggered into the "one" state. The counter skips from the 7th to the 14th binary state, as shown in *Fig. 3,* and thereby produces a decimal count.

For reliable resetting, a voltage which is positive with respect to the emitters is applied to the bases of the transistors of the flip-flops to be reset. This circuit is shown in *Fig. 4.* Under full-load conditions this resetting voltage must be more positive than the voltages of all the emitters in the three decades. The nominal voltage on the emitters is —3 volts, and ground potential is needed to insure reliable operation at high temperatures. Therefore a reset voltage of —1 volt was chosen because it represents a voltage greater than —3 volts and less than 0 volts or ground.

The emitter resistor of the output stage is tapped to provide this —1 volt reset voltage. Since the ratio

of the current required by the output stage to the current required by the reset circuit is very large, the use of this tapped resistor causes a negligible reaction. The output of the reset stage, therefore, swings from nearly —1 volt (—1 volt plus V_{CE} of the stage) to —12 volts. This output is fed directly to the plates of the reset diodes, and the cathodes of these diodes are, in turn, connected directly to the appropriate bases through the "count-selector switch," as shown in *Figs.* 5 and 6.

After the binary-to-decimal conversion was established, the reset switching was determined. In *Fig.* 3, the left digit of the number represents the state of the 4th flip-flop, the second digit represents the state of the 3rd flip-flop, and so on. The desired count is then established by means of a four-wafer switch which pre-sets the states of the flip-flops.

The reset circuit, triggered by the output stage, is turned on during the reset period. The reset circuit, in turn, applies a —1 volt potential to the bases of the transistors to be reset, and turns them off. When counting is resumed, the reset circuit is turned off by the output stage. The reset circuit is then disconnected from the decades by means of a reverse bias of 9 volts applied to the reset diodes.

Input Circuitry

The equipment was designed to provide input signals to the counter by means of two methods. The first input consists of a mechanically operated microswitch which provides a signal which varies from ground to —12 volts. As shown in *Fig.* 5, capacitor C is placed across this switch to prevent erroneous triggering caused by transients produced by switch chatter. A second input is provided by a Schmitt

Binary	F-F 4	F-F 3	F-F 2	F-F 1	Decimal
0	0	0	9	0	0
1	0	0	0	1	1
2	0	0	1	0	2
3	0	0	1	1	3
4	0	1	0	0	4
5	0	1	0	1	5
6	0	1	1	0	6
7	0	1	1	1	7
8	1	0	0	0	
9	1	0	0	1	
10	1	0	1	0	Cancelled By Feedback
11	1	0	1	1	
12	1	1	0	0	
13	1	1	0	1	
14	1	1	1	0	8
15	1	1	1	1	9
0	0	0	0	0	0

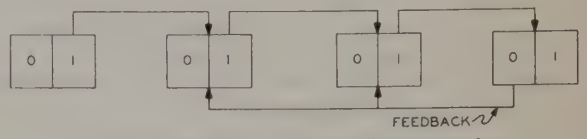

Fig. 3—Binary to decimal conversion.

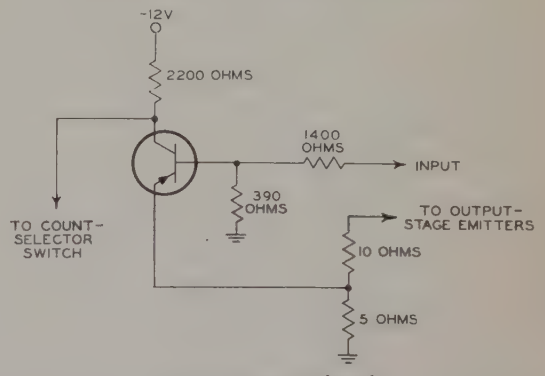

Fig. 4—Reset circuit.

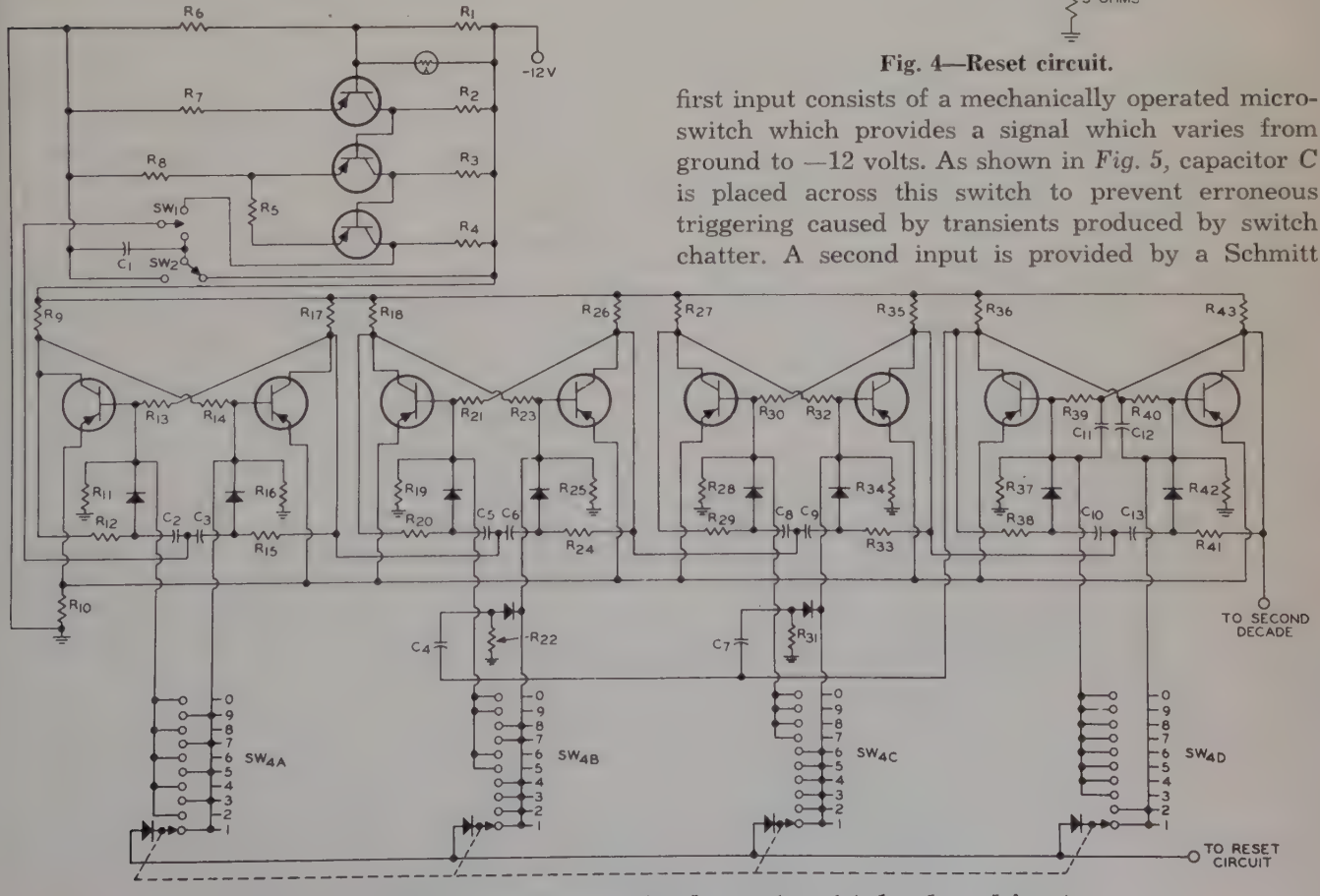

Fig. 5—Low-speed transistorized decade counter—1st decade and input.

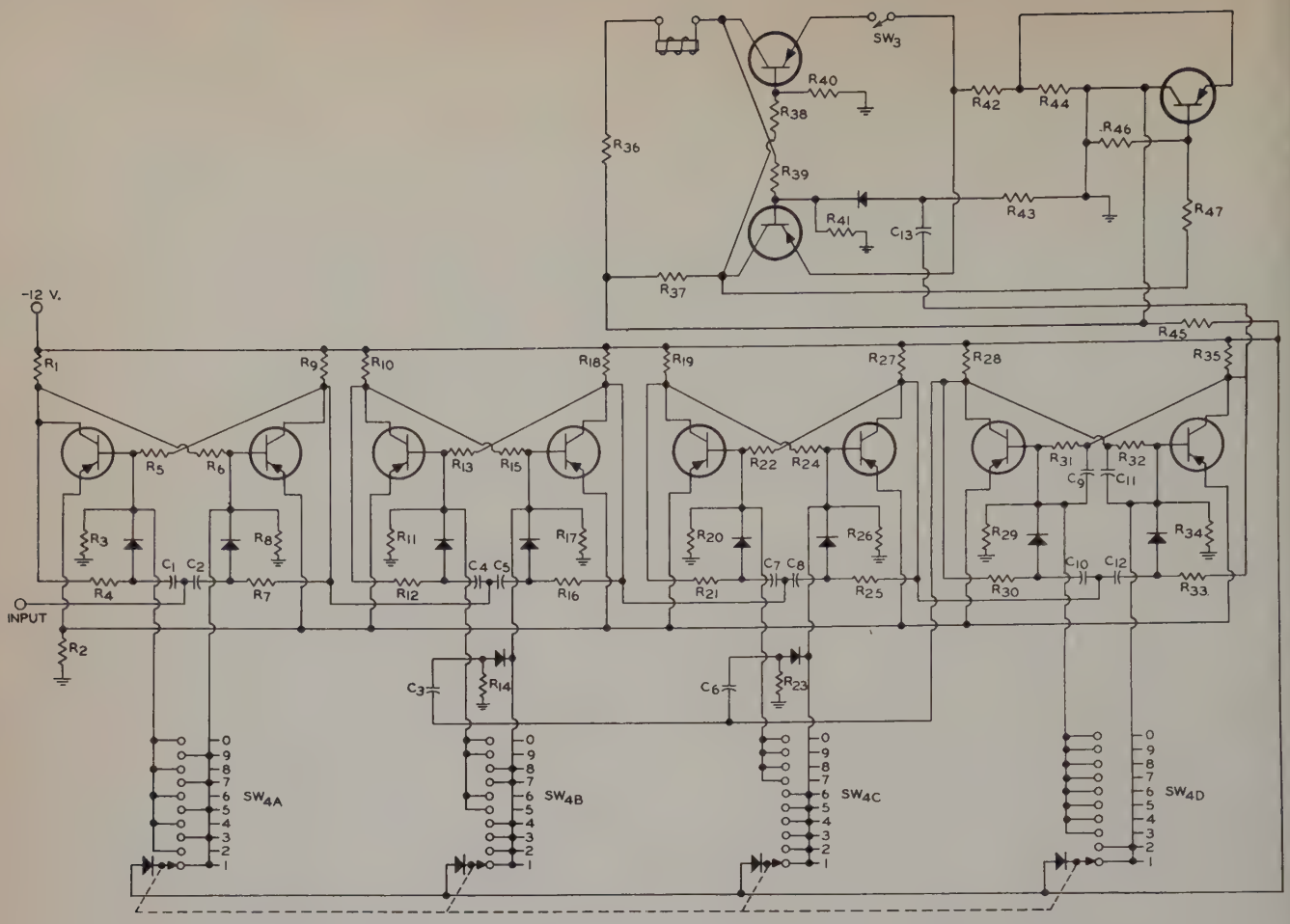

Fig. 6—Low-speed transistorized decade counter—2nd decade reset circuit and output.

circuit driven by an amplified signal from a photocell. The unit used in this application was a Clairex type CL-3 crystal photocell. As used in the test circuit, the cell had a dark resistance of approximately 50 megohms and a light resistance of approximately 100,000 ohms.

The input signal provided by the photocell is amplified by a temperature-stabilized amplifier, the operating point of which is determined by the Schmitt-circuit requirements. A complete analysis of the Schmitt circuit[2] and the class A amplifier[3] can be found in the literature.

Output Circuit Design

The bistable output circuit for this counter was designed to drive a 6 volt, 200-milliampere relay, as shown in *Fig. 6*. The output circuit is triggered into one state by the output of the last decade. It is then returned to the other state by means of an externally operated switch. As an alternative, this output stage could be transformed into a monostable stage, which can be triggered by the last decade, and then returned to its original state after some predetermined time.

Sufficient power to drive the output stage was obtained by the redesign of the 4th flip-flop in the final decade. This revision required that the collector current of the transistors used in the 4th flip-flop circuit be raised from the nominal 5-milliampere value to 25-milliamperes. The same conditions employed in the design of the binary flip-flops were used in the design of the bistable output and the 4th flip-flop of the final decade.

A complete counter consisting of two decades was constructed using RCA type 2N406 and 2N270 transistors and 1N38A diodes. The counter operated satisfactorily at temperatures up to 55 degrees centigrade with power-supply variations of ± 50 per cent.

References

1. "Design of High-Speed Transistor Decimal Counter With Neon-Bulb Readout," R. D. Lohman, 1957 *Westcon Convention Record*, Part 5, p. 49.
2. "How To Design Transistorized Schmitt Triggers"; Richard B. Hurley, *Electronics Equipment*, August 1956.
3. "Transistor Audio Amplifiers"; Richard F. Shea, John Wiley & Sons, Inc., May 1955.

Exact Calculations for Class A and B Transformer Coupled Amplifiers

J. S. MacDOUGALL*

Power transistor circuits operated under large signal conditions are limited in their power output capablities by the "saturation resistance" and the supply voltage. Formula's derived to include this information will allow exact calculation of Class A and B stage operating conditions and eliminate entirely the guesswork involved in Class A design. As a result of the study simple design procedures have been detailed for Class A and B designs which allow very good prediction of circuit performance.

The Meaning of "Saturation Resistance"

Examination of the typical transistor collector characteristic as given in *Fig. 1* shows that there is a line whose slope has the dimensions of inverse resistance which describes the drive limit or saturation of the transistor. Although the idealized characteristic may show a sharp saturation point an expanded plot will show a relatively wide transition region. It thus becomes a problem in the practical case to determine exactly where a "saturation line" should be drawn. In a high power stage the line would be drawn very close to the ideal limit but in an audio amplifier the line is drawn beyond the knee of the collector curves to give low distortion. Hence the exact placing of the saturation line will depend on the particular application.

Since the slope of the saturation line has the units of mhos (or reciprocal ohms) it is often given as a resistance called the "saturation resistance." This saturation resistance will represent the output impedance of the transistor when used as a switch or the ohm's law limit on load current when the transistor is used as a linear amplifier.

It should be noted that a saturation resistance parameter is frequently stated for power transistors which can be very misleading since it can depend very much on the beta used for testing. For instance, a transistor having a small signal beta of 100 may be tested for saturation resistance at a beta of 10. Since this gives no information as to the degree of characteristic crowding and hence the amount of distortion present it is essential in all but the meanest stages to examine the collector characteristic personally and form one's own conclusion as to the correct "saturation resistance" for the particular application.

The usefullness of the saturation resistance is extended when it is realized that since it represents a limitation on *transistor* performance it may have added to it other collector circuit series resistance and hence give a new value which will represent total *circuit* performance. Thus the saturation resistance quantity in the formulas should equal the collector saturation resistance as determined from the collector characteristic plus any series emitter bias resistance plus in some cases, the transformer winding resistance.

Designing a Class "A" Stage for Sine or Square Wave Operation

A typical class A stage as shown in *Fig. 2* is required to deliver power to a load, R_L, through the transformer. A definition of terms is given below:

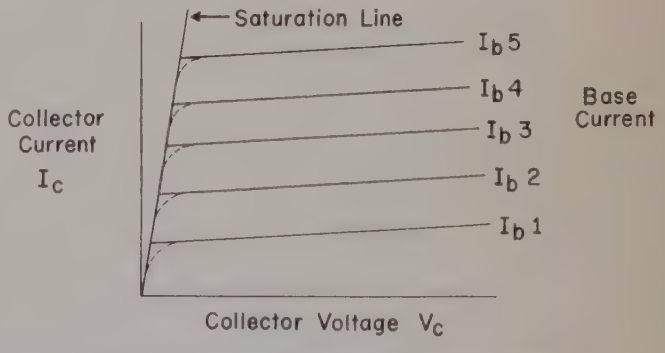

Fig. 1—Idealized collector characteristic.

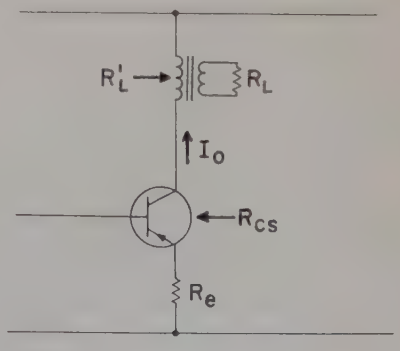

Fig. 2—Typical Class A stage.

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R_{cs} = Collector saturation resistance
$R_s = R_{cs} + R_e$
R_L' = Reflected load resistance
I_o = D.C. collector bias current
P_{om} = Transistor circuit power delivered to transformer
η = Circuit efficiency at maximum power output (P_{om})
V_{cc} = Collector supply voltage
P_{dm} = Highest possible transistor collector dissipation

Using the equations derived in Appendix I a design procedure is given in Table I for a class A transformer coupled stage.

Illustrative Example

A Raytheon 2N1660 transistor is required to deliver two watts into a resistive load when operated in a 24 volt system as a class A amplifier, with a sine wave input.

R_{cs} for this device is four ohms and the emitter stabilization resistor is five ohms unbypassed.

Step 1. $R_s = R_{cs} + R_e = 4 + 5 = 9$ ohms

Step 2. The *d-c* bias current will be given by:

$$I_o = \frac{24}{4 \times 9}\left[1 - \sqrt{1 - \frac{16 \times 9 \times 2}{(24)^2}}\right]$$
$$= .195 \doteq 200\ ma$$

Step 3. The load seen by the collector will be given by

$$R_L' = \frac{2\ R_s}{\frac{V_{cc}\ I_o}{2\ P_{om}} - 1}$$

$$= \frac{18}{\frac{24 \times 0.2}{4} - 1}$$

$$= 90 \text{ ohms}$$

Step 4. The circuit efficiency at full output will be

$$\eta = \frac{P_{om}}{V_{cc}\ I_o}$$

$$= \frac{2}{24 \times 0.2}$$

$$= 41.7\%$$

Step 5. The maximum dissipation in the transistor is given by

$$P_{cm} = V_{cc}\ I_o = 4.8 \text{ watts}$$

Designing a Class "B" Stage For Sine Or Square Wave Operation

For a class B stage of the type shown in *Fig. 3*, and using the equations derived in Appendix II, a design procedure is given in Table II. A definition of terms is given below and the design procedure follows:

R_{cs} = Collector saturation resistance
$R_s = R_{cs} + R_e$

Table I — Design Procedure For a Class "A" Transformer Coupled Stage

Step	Procedure	Sine Wave	Square Wave
1	Calculate the saturation resistance	$R_s = R_{cs} + R_e$	$R_s = R_{cs} + R_e$
2	Calculate the D.C. bias	$I_o = \frac{V_{cc}}{4R_s}\left[1 - \sqrt{1 - \frac{16R_s\ P_{om}}{V_{cc}^2}}\right]$	$I_o = \frac{V_{cc}}{4R_s}\left[1 - \sqrt{1 - \frac{8R_s\ P_{om}}{V_{cc}^2}}\right]$
3	Find the reflected load resistance required	$R_L' = \frac{2R_s}{\frac{V_{cc}\ I_o}{2\ P_{om}} - 1}$	$R_L' = \frac{2\ R_s}{\frac{V_{cc}\ I_o}{P_{om}} - 1}$
4	Calculate the circuit efficiency	$\eta = \frac{P_{om}}{V_{cc}\ I_o}$	$\eta = \frac{P_{om}}{V_{cc}\ I_o}$
5	The maximum dissipation is	$P_{dm} = V_{cc}\ I_o = \frac{P_{om}}{\eta}$	$P_{dm} = V_{cc}\ I_o = \frac{P_{om}}{\eta}$

R_L' = Reflected load resistance per transistor
P_{om} = Total power output from both transistors
η = Total collector circuit efficiency at maximum power output
P_{dm} = Maximum power dissipation per transistor
V_{cc} = Collector supply voltage
I_m = Maximum *d-c* collector supply current

Illustrative Example

The 2N1660 transistor studied in the previous example is to be used in a class B sine wave amplifier which must deliver a maximum of power output regardless of efficiency.

As explained in Appendix II, maximum power output is obtained when the square root quantity in step one reduces to zero. This is the special case where

$$\eta = \frac{\pi}{8} = 39.3\%$$

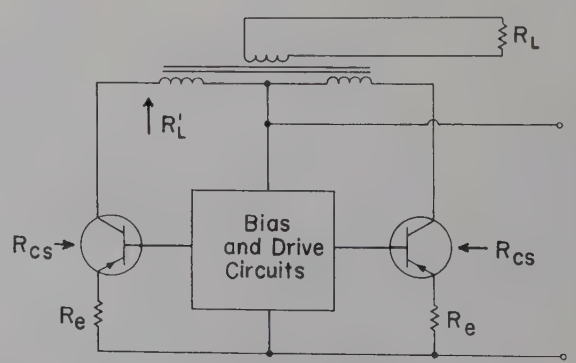

Fig. 3—Typical Class B stage.

ıd the maximum power output is given by:

$$1 - \frac{8\,R_s\,P_{om}}{V_{cc}^2} = 0$$

r, rearranging:

$$P_{om} = \frac{V_{cc}^2}{8\,R_s}$$

$$= \frac{24^2}{8 \times 4} = 18 \text{ watts}$$

The design may now be carried through by following steps 2, 3 and 4 to obtain:

$$R_L' = R_s = 4 \text{ ohms}$$

$$P_{dm} = \frac{V_{cc}^2}{\pi^2 R_L'} = 14.5 \text{ watts}$$

$$I_m = \frac{2}{\pi}\left[\frac{V_{cc}}{2\,R_s}\right]$$

$$= 1.91 \text{ Amps } d\text{-}c.$$

Table II — Design Procedure For a Class "B" Transformer Coupled Stage

Step	Procedure	Sine Wave	Square Wave
1	Calculate the circuit efficiency	$\eta = \frac{\pi}{8}\left[1+\sqrt{1-\frac{8R_s P_{om}}{V_{cc}^2}}\right]$	$\eta = \frac{1}{2}\left[1+\sqrt{1-\frac{4\,P_{om}\,R_s}{V_{cc}^2}}\right]$
2	Calculate the reflected load resistance	$R_L' = \frac{4\eta\,R_s}{\pi - 4\,\eta}$	$R_L' = \frac{\eta\,R_s}{1-\eta}$
3	The maximum power dissipation per transistor will be	$P_{dm} = \frac{V_{cc}^2}{\pi^2 R_L'}$	$P_{dm} = \frac{V_{cc}^2}{8\,R_L'}$
4	The maximum D.C. supply current will be	$I_m = \frac{2}{\pi}\left[\frac{V_{cc}}{R_s+R_L'}\right]$	$I_m = \left[\frac{V_{cc}}{R_s+R_L'}\right]$

Appendix I

Derivation of Class "A" Amplifier Design Equations

A glossary of terms to be used in the derivation is given below:

V_{cc} = D-C collector supply voltage
I_o = D-C collector supply current
V_{cs} = Minimum collector voltage at saturation
I_{cs} = Maximum collector current at saturation
R_s = "Saturation resistance" as defined earlier
R_L' = Reflected load resistance seen by the collector
P_d = Collector dissipation
P_{om} = Transistor circuit power delivered to transformer
η = Collector circuit efficiency at maximum power output
I_c = Minimum value of collector current during signal
V_c = Peak value of collector voltage during signal
P_{dm} = Maximum collector dissipation

The load line to be examined is drawn on a collector characteristic in *Fig. 4*. This load line is not the usual "theoretical" load line which can only be drawn if there is no saturation resistance but is the actual line that until now could only be obtained by trial and error.

Sine Wave Analysis

From *Fig. 4* certain equations are immediately evident. Assuming bias is to the middle of the useful load line:

$$I_o = \frac{I_{cs}}{2} \qquad (1)$$

$$P_{om} = \frac{(V_{cc} - V_{cs})\,I_{cs}}{4} \qquad (2)$$

$$R_s = \frac{V_{cs}}{I_{cs}} \qquad (3)$$

$$R_L' = 2\,\frac{(V_{cc} - V_{cs})}{I_{cs}} \qquad (4)$$

The general equation for collector dissipation is:

$$P_d = \frac{1}{2\,\pi}\int_0^{2\pi} p\,d\omega t \qquad (5)$$

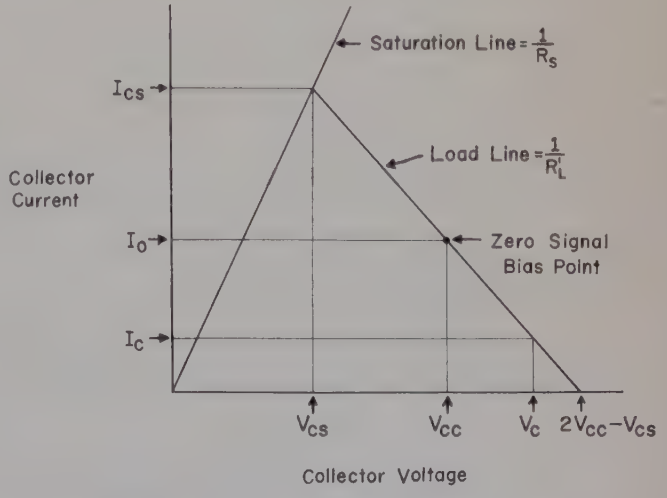

Fig. 4—Class A collector characteristic.

The instantaneous collector power dissipation consists of:

$$p = V_{cc} I_o - i_c^2 R_L' \tag{6}$$

where

$$i_c = (I_o - I_c) \sin \omega t$$

Substituting Eq. (1)

$$i_c = \left(\frac{I_{cs}}{2} - I_c\right) \sin \omega t \tag{7}$$

Combining Eq. (1), (4), (7), and (6) in (5) gives:

$$P_d = \frac{1}{2\pi} \int_0^{2\pi} \left[\frac{V_{cc} I_{cs}}{2} - 2\left(\frac{V_{cc} - V_{cs}}{I_{cs}}\right)\left(\frac{I_{cs}}{2} - I_c\right)^2 \sin^2 \omega t\right] d\omega t$$

$$= \frac{V_{cc} I_{cs}}{2} - I_{cs} (V_{cc} - V_{cs}) \left(\frac{1}{2} - \frac{I_c}{I_{cs}}\right)^2 \tag{8}$$

This is the general equation for the collector dissipation which when solved for the specific case of $I_c = I_{cs}/2$ gives the zero signal dissipation:

$$P_d = \frac{V_{cc} I_{cs}}{2} = V_{cc} I_o = P_{dm} \tag{9}$$

and for the case of $I_c = 0$, gives a value for the collector dissipation at maximum signal of:

$$P_d = \frac{(V_{cc} + V_{cs}) I_{cs}}{4} \tag{10}$$

Since the circuit is operated class A, the input power remains constant under all signal conditions and therefore equals the zero signal collector dissipation. Thus the circuit efficiency is given by:

$$\eta = \frac{P_{om}}{P_{in}\ (d\text{-}c)} = \frac{P_{om}}{V_{cc} I_o} \tag{11}$$

$$= \frac{\frac{V_{cc} - V_{cs}}{4} I_{cs}}{\frac{I_{cs}}{2} V_{cc}} = \frac{1}{2}\left(1 - \frac{V_{cs}}{V_{cc}}\right) \tag{12}$$

However,

$$I_{cs} = \frac{2 (V_{cc} - V_{cs})}{R_L'} \tag{4}$$

and

$$I_{cs} = \frac{V_{cs}}{R_s} \tag{3}$$

Therefore equating Eq. (4) and (3) and rearranging we get:

$$\frac{V_{cs}}{V_{cc}} = \frac{2R_s}{R_L' + 2R_s} \tag{13}$$

Substituting Eq. (13) in (12) and simplifying gives:

$$\eta = \frac{1}{2}\left(\frac{R_L'}{R_L' + 2R_s}\right) \tag{14}$$

and solving Eq. (14) for R_L':

$$R_L' = \frac{4\eta R_s}{1 - 2\eta} \tag{14-A}$$

Also substituting Eq. (11) in (14-A) gives:

$$R_L' = \frac{2R_s}{\frac{V_{cc} I_o}{2 P_{om}} - 1} \tag{15}$$

The power output equation may be manipulated as follows:

$$P_{om} = \frac{V_{cc} - V_{cs}}{4} I_{cs} \tag{2}$$

$$= \frac{V_{cc}^2}{4}\left(1 - \frac{V_{cs}}{V_{cc}}\right) \times \frac{I_{cs}}{V_{cs}} \times \frac{V_{cs}}{V_{cc}}$$

Then by substitution of Eq. (13), (3) and simplification:

$$P_{om} = \frac{V_{cc}^2 R_L'}{2(R_L' + 2R_s)^2}$$

Substituting Eq. (14-A) for R_L' gives:

$$P_{om} = \frac{V_{cc}^2}{2R_s} \eta (1 - 2\eta) \tag{16}$$

Substituting for η (Eq. 11) in Eq. 16 gives:

$$I_o = \frac{V_{cc}}{2R_s}\left(1 - \frac{2 P_{om}}{V_{cc} I_o}\right)$$

Solving for I_o results in the key equation:

$$I_o = \frac{V_{cc}}{4R_s}\left[1 \pm \sqrt{1 - \frac{16 R_s P_{om}}{V_{cc}^2}}\right] \tag{17}$$

Equation (17) indicates that two extreme bias points are possible, one with low current high voltage swing and one with high current low voltage swing. For simplification of transformer design it is desirable to use the low current bias point which means using the "minus" in Equation (17).

Equation (17) also gives information about the circuit power limitations. Between the two load lines described by the two extreme bias points there will be a load line representing the maximum power the circuit could ever possibly deliver. This occurs when the quantity under the square root sign equals zero. Therefore at maximum possible power output.

$$I_o = \frac{V_{cc}}{4 R_s} \tag{18}$$

$$\text{at } P_{om} = \frac{V_{cc}^2}{16\,R_s} \tag{19}$$

Therefore combining Eq. (18) and (19) in Eq. (11) gives $\eta = 25\%$ which is the efficiency at maximum possible power output. Substitution of this value for η back into Equation (14-A) shows that $R_L' = 2R_s$ represents the minimum useable load resistance.

Square Wave Analysis

Referring to *Fig. 4* again and writing the obvious equations we get:

$$I_o = \frac{I_{cs}}{2} \tag{1}$$

$$P_{om} = \frac{(V_{cc} - V_{cs})\,I_{cs}}{2} \tag{20}$$

$$R_s = \frac{V_{cs}}{I_{cs}} \tag{3}$$

$$R_L' = \frac{2(V_{cc} - V_{cs})}{I_{cs}} \tag{4}$$

Without resorting to integration it is clear that the maximum collector dissipation will be:

$$P_{dm} = V_{cc}\,I_o \tag{9}$$

and the collector dissipation at maximum output is given by:

$$P_d = \frac{V_{cs}\,I_{cs}}{2} \tag{21}$$

Then carrying out the analysis exactly as before the following key equations are obtained:

$$\eta = \frac{R_L'}{R_L' + 2R_s} \tag{22}$$

$$R_L' = \frac{2\eta\,R_s}{1 - \eta} \tag{22-A}$$

$$P_{om} = \frac{V_{cc}^2}{2R_s}\,\eta\,(1 - \eta) \tag{23}$$

$$I_o = \frac{V_{cc}}{4R_s}\left[1 \pm \sqrt{1 - \frac{8R_s\,P_{om}}{V_{cc}^2}}\right] \tag{24}$$

Compare Eq. (24) with Eq. (17)
Also, at maximum possible power output:

$$I_o = \frac{V_{cc}}{4R_s} \tag{25}$$

$$P_{om} = \frac{V_{cc}^2}{8\,R_s} \tag{26}$$

$$\eta = 50\%$$

and $R_L' = 2R_s$

Appendix II

Derivation of Class "B" Amplifier Design Formulas

Definition of Terms

R_{cs} = Collector saturation resistance
$R_s = R_{cs} + R_e$
R_L' = Reflected load resistance seen by each collector
P_{om} = Total power output from both transistors
η = Total collector circuit efficiency at maximum power output
P_{dm} = Maximum power dissipation per transistor
V_{cc} = Collector supply voltage
I_m = Maximum *d-c* collector supply current
I_{cs} = Collector current at saturation
V_{cs} = Collector voltage at saturation

Sine Wave Operation

Consider the collector characteristic graph given in *Fig. 5*. The peak signal swing along the load line is limited at the bottom by the saturation line. The saturation line location may be set by definition to suit the particular application and its distortion requirements.

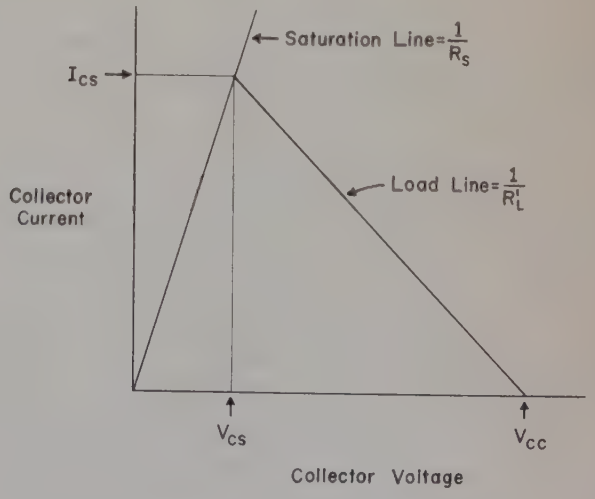

Fig. 5—Class B collector characteristic.

From the characteristics it is immediately apparent that:

$$R_s = \frac{V_{cs}}{I_{cs}} \tag{1}$$

$$R_L' = \frac{V_{cc} - V_{cs}}{I_{cs}} \tag{2}$$

$$P_{om} = \frac{(V_{cc} - V_{cs})\, I_{cs}}{2} \tag{3}$$

The maximum dissipation at each collector is a well known equation obtained as follows:

$$P_d = \frac{1}{2\pi}\int_0^{\pi} vi\, d\omega t = \frac{1}{2\pi}\int_0^{\pi} (V_{cc} - R_L'\, i)\, id\omega t$$

If $i = I_c \sin \omega t$, then solving:

$$P_d = \frac{V_{cc}\, I_c}{\pi} - \frac{I_c^2\, R_L'}{4} \tag{4}$$

The maximum dissipation occurs at:

$$0 = \frac{dP_d}{dI_c} = \frac{V_{cc}}{\pi} - \frac{I_c\, R_L'}{2}$$

$$\text{or when } I_c = \frac{2V_{cc}}{\pi\, R_L'} \tag{5}$$

Substituting this value of I_c into Eq. (4) gives the maximum dissipation equation:

$$P_{dm} = \frac{1}{\pi^2}\,\frac{V_{cc}^2}{R_L'} \tag{6}$$

Also equating Eq. (1) and (2) and solving:

$$\frac{V_{cs}}{V_{cc}} = \frac{R_s}{R_L' + R_s} \tag{7}$$

The total output circuit efficiency is given by:

$$\eta = \frac{P_{om}}{P_{om} + 2\, P_d}$$

By substitution of Equations (4) and (7), at the point where $I_c = I_{cs}$, this becomes:

$$\eta = \frac{\pi}{4}\left(\frac{R_L'}{R_L' + R_s}\right) \tag{8}$$

Or rearranging:

$$R_L' = \frac{4\,\eta\, R_s}{\pi - 4\,\eta} \tag{8-A}$$

If the power output, Eq. (3), is expanded so that Eq. (1) and (7) may be substituted we get:

$$P_{om} = \frac{V_{cc}^2\, R_L'}{2(R_s + R_L')^2} \tag{9}$$

Substituting Eq. (8-A) into (9) and solving for the efficiency gives:

$$\eta = \frac{\pi}{8}\left[1 \pm \sqrt{1 - \frac{8R_s\, P_{om}}{V_{cc}^2}}\right] \tag{10}$$

This shows two possible load lines but since it is desirable to have as high an efficiency as possible, the plus sign is retained in the equation of choice.

As with the class A amplifier, this type of equation gives the conditions for maximum possible circuit power output, namely:

$$P_{om} = \frac{V_{cc}^2}{8R_s} \tag{11}$$

This will occur at an efficiency of

$$\eta = \frac{\pi}{8} = 39.3\% \tag{12}$$

An efficiency of 39.3% will then represent a bottom limit in checking for possible design errors. This maximum possible power output will occur when

$$R_L' = R_s \tag{13}$$

The maximum *d-c* collector supply current is the average value of the total pulses flowing in the collector leads. This is given by:

$$I_m = \frac{2}{\pi}\, I_{cs}$$

substituting Eq. (7) gives:

$$I_m = \frac{2}{\pi}\left(\frac{V_{cc}}{R_s + R_L'}\right) \tag{14}$$

Square Wave Operation

Referring to *Fig. 5* again and writing the obvious equations we get:

$$R_s = \frac{V_{cs}}{I_{cs}} \tag{1}$$

$$R_L' = \frac{V_{cc} - V_{cs}}{I_{cs}} \tag{2}$$

$$P_{om} = (V_{cc} - V_{cs})\, I_{cs} \tag{15}$$

$$P_d = \frac{V_{cc}\, I_c - I_c^2\, R_L'}{2} \tag{16}$$

The maximum power dissipation may be found by differentiating Eq. (16) to get:

$$0 = \frac{dP_d}{dI_c} = \frac{V_{cc}}{2} - I_c\, R_L'$$

$$I_c = \frac{V_{cc}}{2R_L'} \tag{17}$$

Substituting Eq. (17) into (16) gives:

$$P_{dm} = \frac{V_{cc}^2}{8R_L'} \tag{18}$$

By a process similar to the sine wave analysis, the efficiency at maximum power output is:

$$\eta = \frac{R_L'}{R_L' + R_s} \tag{19}$$

$$R_L' = \eta \frac{R_s}{1 - \eta} \tag{19-A}$$

Also the maximum power output is:

$$P_{om} = V_{cc}^2 \frac{R_L'}{(R_L' + R_s)^2} \tag{20}$$

Which by substitution of Eq. (19-A) becomes:

$$\eta = \frac{1}{2}\left[1 \pm \sqrt{1 - \frac{4P_{om} R_s}{V_{cc}^2}}\right] \tag{21}$$

Maximum possible power output will be:

$$P_{om} = \frac{V_{cc}^2}{4 R_s} \tag{22}$$

This occurs at:

$$\eta = 50\% \text{ and when } R_L' = R_s$$

The maximum D.C. collector supply current is:

$$I_m = I_{cs} = \frac{V_{cc}}{R_s + R_L'} \tag{23}$$

Zener Diode Circuits For Stable Transistor Biasing†

Part 1

J. KABELL* V. H. GRINICH*

The stabilization of the *d-c* operating point of transistor amplifiers by the use of Zener diodes is discussed. The circuit using the Zener diode has a high degree of stability with a minimum drain of power from a single simple power supply. The operating point of the transistor is established in a more stable manner than in commonly used bias circuit arrangements because it is much less affected by variations of temperature and variations among transistors. Design methods and experimental results with germanium and silicon units are given for the Zener diode scheme and compared to conventional methods of biasing.

WHEN THE CIRCUIT DESIGNER IS LIMITED to a single source of power supply voltage, the design of a transistor amplifier stage involves a compromise between minimum power consumption and the stability of the *d-c* operating point of the transistor with respect to variations in ambient temperature and variations in parameters among transistors. By using silicon Zener diodes to establish voltage levels certain transistor circuit *d-c* bias methods can be evolved that either eliminate the necessity for such a compromise or make possible a more desirable compromise.

One figure of merit for the *d-c* bias stability of a transistor amplifier stage is the partial derivative of total collector current, I_c, with respect to collector leakage current, I_{c0}. This figure of merit is sometimes called the stability factor S[1], and the degree of stability of a circuit is inversely proportional to the magnitude of S. Another figure of merit, T, which indicates the relative tolerance of circuits to transistor substitution will be introduced.

The normal method used for biasing a common base stage with two sources of power supply voltage and a large series resistor in the emitter bias supply lead gives a value of S near unity for the stage. However, when only one source of power supply voltage is available, it is necessary either to bias the transistor in such a manner that variations in collector leakage currents are amplified along with the desired signal or to approximate a second voltage source by means of a resistive voltage divider connected across the primary voltage source. The first alternative usually results in a circuit having S nearly equal to h_{FE} of the transistor; the second alternative reduces S at the expense of increasing power drain in the voltage

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*Fairchild Semiconductor Corporation

[1] Shea, et al., Principles of Transistor Circuits, p. 99 (John Wiley and Sons, N.Y., (1953).

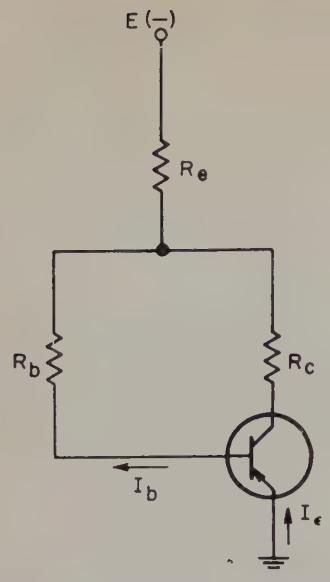


Fig. 1—"Standard" resistive biasing network.

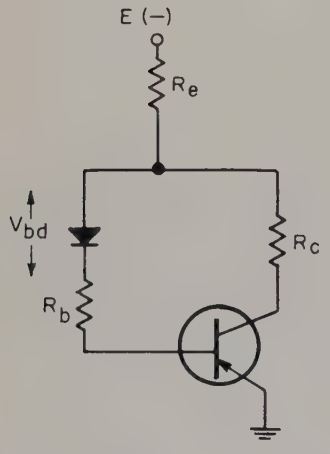


Fig. 2—Zener diode biasing network.

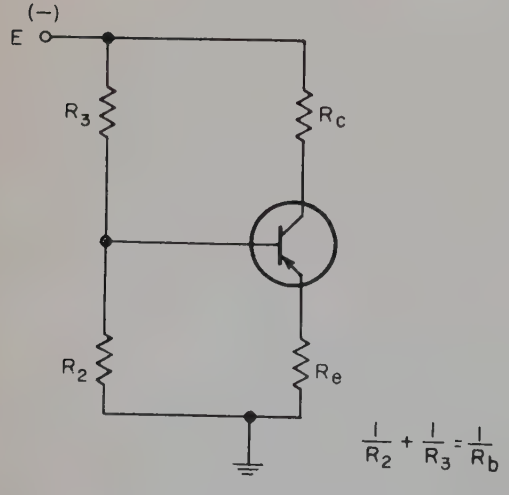


Fig. 3—"Brute force" resistive biasing network.

divider. *D-C* degeneration in the form of emitter lead resistance may also be used to improve stability.

Presented here are several *d-c* bias arrangements for transistor circuits that use the constant avalanche (Zener) voltage property of silicon junction diodes to provide maximum bias stability with minimum power drain, minimum signal degeneration, and relatively few components. In general, the Zener diode is used to control the collector-base voltage of the transistor while a series resistor controls the emitter current. These circuits are described in detail in the following sections and the basic design equations are given.

Stability Factor For Resistive Bias Network

The conventional single-voltage source bias network shown in *Fig. 1* depends on the *d-c* degeneration introduced by resistor R_e to improve the bias stability factor of the circuit, and the stability factor is given by the equation:

$$S = \frac{R_e + R_b}{R_e + R_b\,(1 - h_{FB})} \tag{1}$$

From this equation it can be seen that large values of R_e and small values of R_b are desirable for good stability. Design Equations (1) through (6) relate to the circuit of *Fig. 1*. Since the value of R_b is determined by the base current of the transistor and the *d-c* collector-to-base voltage plus the *d-c* voltage drop across R_c, R_b is necessarily quite large for the usual values of collector voltage and base current.

$$\frac{E - V_{ce}}{I_e} = R_o \tag{2}$$

$$\frac{1}{R_e} + \frac{1}{R_b} = \frac{1}{R_L} \tag{3}$$

Assuming

$$I_b \ll I_e, \text{ and } V_{cb} \simeq 0, \tag{4}$$

then

$$R_o = R_e + R_c \tag{5}$$

$$I_b R_b = V_c + h_{FB} I_e R_c \tag{6}$$

However, if part of the voltage drop normally obtained in R_b is obtained instead by placing a Zener diode in the base lead (the circuit is shown in *Fig. 2*) the value of R_b may be reduced and since the voltage drop across the diode is relatively independent of the current flowing through it, S is improved by the corresponding reduction of R_b.* Design equations (7) through (12) apply in this case.

* The result of reducing R_b increases the *a-c* loading but in most cases this effect is negligible. In any case its effects could be included in the design.

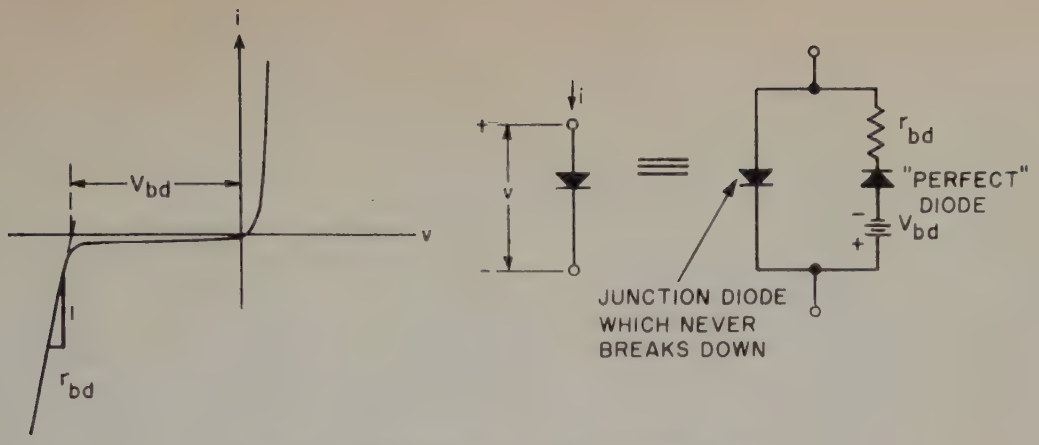


Fig. 4—Characteristics of breakdown diode.

$$S = \frac{R_b + R_e}{R_b\,(1 - h_{FB}) + R_e} \tag{7}$$

$$\frac{E - V_{ce}}{I_e} = R_o \tag{8}$$

$$\frac{1}{R_c} + \frac{1}{R_b} = \frac{1}{R_L}$$

Assuming

$$I_b \ll I_e, \text{ and } V_{cb} \simeq 0, \tag{10}$$

then

$$R_o = R_e + R_c \tag{11}$$

$$I_b R_b + V_{bd} = V_{ce} + h_{FB} I_e R_e \tag{12}$$

Figure 3 shows another common method referred to as the "brute force" method of obtaining *d-c* bias from a single power source. The design equations are (13) through (18). In this circuit R_2 and R_3 form a voltage divider which sets the base voltage of the transistor, and R_e provides *d-c* degeneration. The stability factor depends on the values of the resistors of the voltage divider, R_2 and R_3, which in turn may be limited by signal impedance consideration. For the circuit of *Fig. 3:*

$$S = \frac{R_e + \dfrac{R_2 R_3}{R_2 + R_3}}{R_e + (1 - h_{FB})\,\dfrac{R_2 R_3}{R_2 + R_3}} \tag{19}$$

$$S = \frac{R_b + R_e}{R_b\,(1 - h_{FB}) + R_e} \tag{13}$$

where

$$\frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{R_b}$$

$$\frac{E - V_{ce}}{I_e} \triangleq R_o$$

$$\frac{1}{R_c} + \frac{1}{R_b} \triangleq \frac{1}{R_L}. \tag{15}$$

Assuming

$$I_b \ll I_e \text{ and } I_b \ll \frac{E}{R_2 + R_3},$$

and

$$V_{cb} \simeq 0, \tag{16}$$

$$R_o = R_c + R_e \tag{17}$$

$$1 + \frac{R_3}{R_2} = \frac{E}{I_c R_e} \tag{18}$$

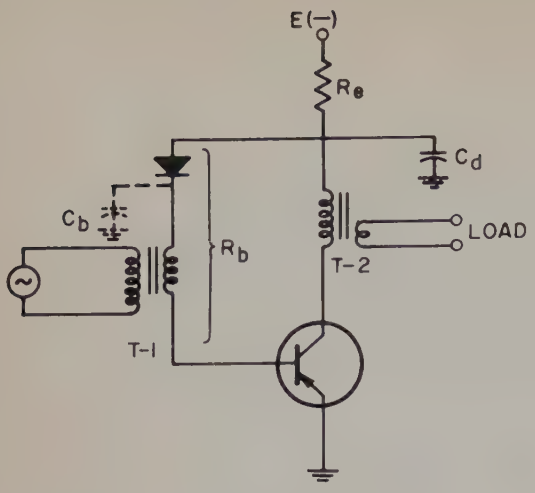
Equations (1) and (19) are similar in that R_e is the same and R_2 and R_3 in parallel are equivalent to R_b. It is clear that the stability factor may be improved within limits (set by signal impedance considerations) by reducing the value of R_2 and R_3 which in turn increases the power consumed by the circuit.

Characteristics Of Breakdown Diodes

The volt-ampere characteristics of a Zener junction diode, *Fig. 4(a)*, can be approximated by the model in *Fig. 4(b)* composed of a junction diode having infinite breakdown voltage in parallel with a series circuit; this series circuit consists of a "perfect" diode (zero voltage drop in forward direction, zero current in back direction), a resistance r_{bd}, representing the diode impedance in the avalanche condition, and a source of e.m.f., V_{bd}, that is equal to the Zener voltage. (At the present time commercially available Zener diodes are obtainable with avalanche voltages from 3.7 to 500 volts.) The resistance r_{bd} initially decreases with current.

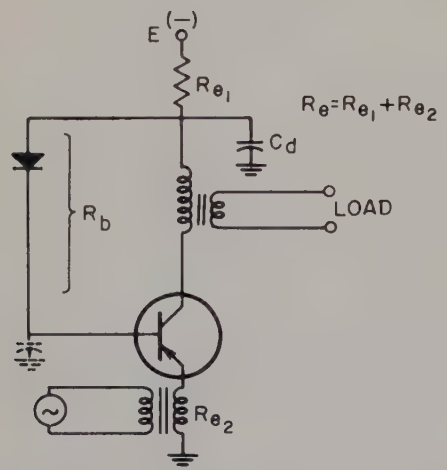
Variations of avalanche voltage with temperature change are small enough to be considered negligible for the applications under consideration.

A certain minimum *d-c* diode current is required for stable operation in the avalanche region and can be obtained by specifying either (1) transistor char-



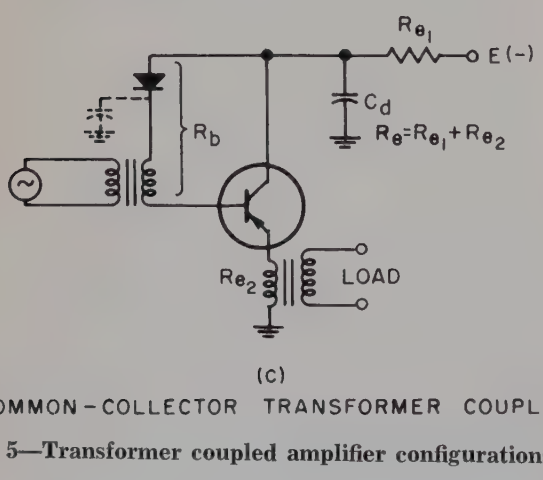
(a)

COMMON-EMITTER TRANSFORMER COUPLED



(b)

COMMON-BASE TRANSFORMER COUPLED



(c)

COMMON-COLLECTOR TRANSFORMER COUPLED

Fig. 5—Transformer coupled amplifier configurations.

acteristics and operating points which provide the necessary base current or (2) additional circuit elements that are discussed later. At current levels close to the knee of the curve where avalanche begins, many diodes exhibit either a high internally generated noise or a high *a-c* impedance, or both. Therefore operation near this point should be avoided.

Circuit Configurations

Figures 5(a), (b), and *(c)* show the method of using Zener diodes with transformer coupling for the common-emitter, common-base, and common-collector configurations. The resistance R_b consists of the *d-c* resistance of transformer winding (T-1) plus the resistance r_{bd} of the Zener diode. (The base-lead resistance of the transistor r_{bb}, may have to be considered in some cases.) Capacitor C_d prevents signal degeneration through R_e. In cases where r_{bd} causes excessive loss of gain or where the diode introduces excessive noise a bypass capacitor C_b as shown in *Fig. 5(a)* may be used.

The capacitor C_b should be used when (1) the Zener diode impedance in the avalanche region is sufficiently high to lower the gain or (2) the noise introduced by the diode may be objectionable.

In the three configurations of *Fig. 5* the *d-c* circuit is the same except that the transformer is located in different branches and hence the *d-c* resistance is different. For most applications the resistance of the input transformer winding may be made small compared with R_e, and therefore S may be made very nearly unity.

Instead of complete transformer coupling, inductive coupling (L_1, C_1) as shown in *Fig. 6* may be used in combination with transformer coupling (T-2). Obviously T-2 can also be replaced by an *LC* combination.

Zener diode bias stabilization may also be used with *RC* coupling as illustrated in *Fig. 7*. In the *RC* case the resistance in the base lead is usually higher than in the case of inductive coupling, but a good stabilization factor may be obtained with lower power consumption than is possible with conventional resistance stabilization.

In terms of low frequency response the use of the brute force technique for *a-c* common emitter operation requires a large capacitor across R_e so that the input impedance at the base ($\simeq h_{fe}/j\omega C_e$) is small compared to the source impedance driving the base. For the breakdown diode case, the equivalent capacitor is C_d the decoupling capacitor which must be only large enough so that the shunt feedback is negligible. By considering these effects one can obtain a design for the Zener diode case where the required capacitor can be significantly smaller for the same low frequency characteristic. Hence, not only is the Zener diode case more economical in power dissipation but also it can reduce the cost and size of the capacitors necessary for low frequency response.

A final circuit that can be used for transformer coupled inputs permits one to design with the Zener diode used in the conventional voltage regulator mode except that the current and power drain requirements are reduced since the diode is in the base circuit. The circuit is shown in *Fig. 7*.

The design equations are as follows:

$$I_c \simeq \frac{V_{bb}}{R_e} \tag{19}$$

$$R_b = \frac{E - V_{bb}}{I_d + I_b} \tag{20}$$

Design so $I_d > I_b$ and if $R_c >> R_d$, then $S \simeq 1$.

Design Data

The following design data pertain to an *RC* coupled common-emitter video amplifier of the configuration shown in *Fig. 8*. Given the supply voltage E the desired interstage loading resistance R_L (determined by bandwidth considerations), and a specified operating point I_e and V_c, values of R_b and R_c that give the minimum value of S may be calculated as follows. Defining $(E—V_c)$ $I_c=R_o$, and assuming $I_b \gg I_e$ and that $V_{cb} \simeq 0$, then since $R_c + R_e = R_o$ and $1/R_L = 1/R_b + 1/R_C$*, we have:

$$S = \frac{R_L R_c - (R_c - R_o)(R_c - R_L)}{(1 - h_{FB}) R_L R_c - (R_c - R_o)(R_c - R_L)}. \tag{21}$$

This has a minimum at the value:

$$R_c = \sqrt{R_o R_L} \tag{22}$$

which is (under the above assumptions) independent of h_{FB}. This gives for the optimum value of S:

$$S_{opt.} = \frac{R_L + (R_o - \sqrt{R_L})^2}{(1 - h_{FB}) R_L + (\sqrt{R_o} - \sqrt{R_L})^2} \tag{23}$$

In order to illustrate the design formula, assume the following conditions:

$$\begin{aligned} E &= 12v \\ R_L &= 0.5K \\ I_e &= 1\ ma \\ V_{ce} &= 4v \end{aligned}$$

Also assume these transistor values at 1 *ma* and 4 *V*. (This is current coming out of the base for a *pnp*.)

$$\begin{aligned} I_b &= 5\ \mu a \\ h_{FE} &= 100. \end{aligned}$$

then

$$R_o = \frac{12 - 4}{1} = 8K$$

$$\begin{aligned} R_c &= \sqrt{(8)(0.5)} = 2K \\ V_{bd} &= 6v \\ R_e &= 6K \end{aligned}$$

$$R_b = \left(\frac{1}{0.5} - \frac{1}{2}\right)^{-1} = 0.67K$$

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* If the *a-c* base input impedance of the transistor cannot be neglected, the analysis should be modified by increasing R_L to give the proper *a-c* loading.

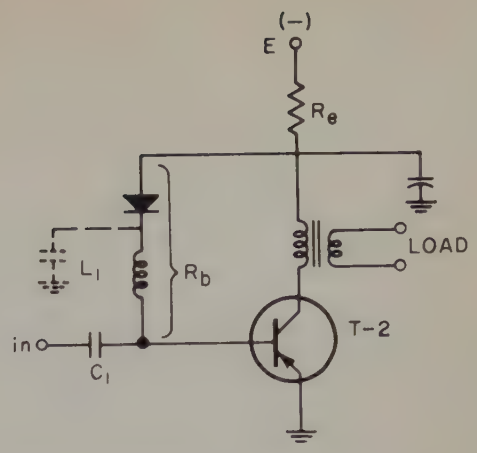


Fig. 6—Hybrid circuit—*LC* coupled input, transformer coupled output.

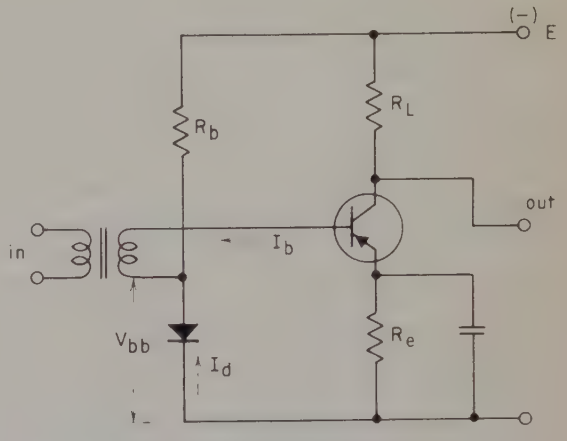


Fig. 7—Use of Zener diode to establish V_{bb}.

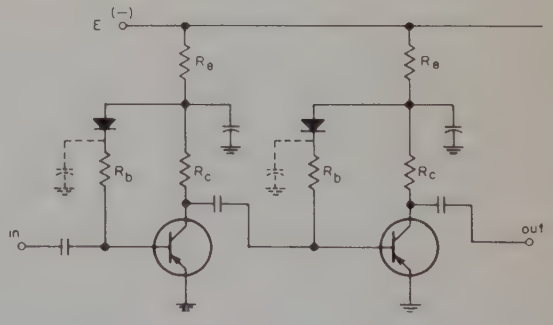


Fig. 8—*RC* coupled video amplifier.

$$S_{opt.} = \frac{0.5 + (2.8 - 0.7)^2}{\frac{0.5}{100} + (2.8 - 0.7)^2} = \frac{4.9}{4.4} = 1.11.$$

For comparison with the standard resistive network stabilization of *Fig. 1* we can write corresponding design equations except that I_b will have to be included in the analysis.

Thus the equations used above for S, R_o and R_L still hold, but the additional condition

$$I_b R_b \simeq V_{ce} + h_{FB} I_e R_c \tag{24}$$

must be satisfied. Combining this with the equation $1/R_L = 1/R_c + 1/R_b$ yields

$$\frac{h_{FB} I_e}{I_b} R_c^2 + \left[\frac{V_{ce}}{I_b} - R_L\left(1 + \frac{I_e}{I_b}\right)\right] R_c - \frac{V_{ce}}{I_b} R_L = 0. \tag{25}$$

Since this quadratic has only one physically significant solution for R_c, this value of R_c can be used to determine R_e and S. The d-c power input, $I_e E$, into this circuit is equal to that of the Zener diode bias circuit. For the same illustrative example we have with $I_b = 5\mu a$,

$$R_c = 0.5K$$
$$R_e = 7.5K$$
$$R_b = 900K$$
$$S = 55.$$

It should be emphasized again that the value of R_b in this case will have to be chosen specifically for each transistor, because small changes in I_b from transistor to transistor can move the operating point an intolerable amount.

For the "brute-force" bias scheme the conditions* listed under *Fig. 3* can be combined to yield the following design data:

$$R_3 = \frac{E\,(S-1)}{I_e\,[1 - S\,(1 - h_{FB})]} \tag{26}$$

$$1 + \frac{R_3}{R_2} = \frac{E}{I_e R_e} \tag{27}$$

where R_e is the larger positive root of the quadratic

$$R_e^2 + \left[R_L - R_o - \frac{1 - S\,(1 - h_{FB})}{S - 1} R_L\right] R_e + \frac{1 - S\,(1 - h_{FB})}{S - 1} R_o R_L = 0. \tag{28}$$

---

* The brute force scheme of *Fig. 3* and the zener-diode bias scheme of *Fig. 2* are equivalent (in regard to stability and loading criteria) as can be seen by making a Thevenin circuit out of R_2, R_3, and E. By circuit element rearrangement this gives a battery $[R_b/(R_2+R_b)]\,E$ in series with R_b in the base lead, the battery then being replaceable by the breakdown diode.

(To be continued)

Versatile Automatic Sequential Tester For Transistor Specification Testing

WHILE THE STRONG EMPHASIS on semiconductor device and materials development continues, automation and mechanization of manufacturing procedures is more and more becoming a prime concern within a maturing transistor industry.

At Philco Corporation's Lansdale Division, the needs of the transistor inspection department were delivered in "project form" to automation design specialists. The outcome was VAST I (Versatile Automatic Sequential Tester), which is now used by Philco semiconductor operations and also is being offered to the electronic component industry in accordance with custom specifications.

Designed to rapidly test large quantities of transistors to a single, programmed specification, VAST I is capable of 20-parameter "go-no-go" testing of 3600 transistors per hour.

The equipment accommodates three operators, though more than two are seldom required. Transistors are inserted in single unit sockets affixed to a conveyor system and are transported sequentially from station to station.

Test set-up is achieved by use of a 2000-bit program card. Information recorded on the program card is then assimilated by card-reader circuits and effectively transposed into circuit adjustments.

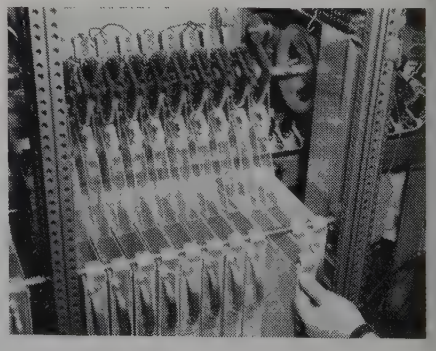
To expedite "check-out" of the circuits after installation of a new program card, and to facilitate in-process monitoring, VAST I is equipped with a simple circuit-check indicator system. If all circuits are functioning properly, a series of indicator lamps on the front panel will light when a monitor-request button is pushed. Monitor jacks are also provided to obtain actual circuit readings.

Each of the individual parameter tests constitutes a "go-no-go" decision by the equipment. This is accomplished by an automatic correlation of transistor test performance with programmed limits on the card. Pick-off mechanisms at every test station immediately remove "no-go" units.

As a precaution against malfunction of a pick-off mechanism, the VAST I tester contains a magnetic memory-core shift register which prevents rejects from proceeding to an "acceptable" station. Individual bins for each station are provided at the rear of the equipment.

As used by Philco's semiconductor operations, VAST I automatically tests the following parameters on each transistor:

a) Leakage currents (I_{EBO}, I_{CBO}, I_{CES}, I_{CER}, I_{CEV})
b) Reach-through voltage



Opened rear quarters reveal transistor pick-off mechanisms and collection bins.

c) Diode breakdown voltages (BV_{CER}, BV_{CES}, BV_{CEO}, BV_{CBO}, BV_{EBO})
d) Saturation voltages (V_{CE}, V_{BE})
e) DC beta (H_{FE})
f) 1000 cycle beta (h_{fe})

Rejected transistors are automatically ejected to various bins which identify the particular parameter the ejected unit did not meet. A provision is made for an inventory count of each type of failure and the number of acceptable units processed. Test circuits are protected from shorts or open circuits as currents and voltages have been limited to non-destructive values.

The VAST I functions as a transistor tester ideally suited for re-test and incoming inspection departments where the devices are tested to finally determine whether or not they meet the specifications that have been assigned to each. This requires the testing of large quantities of transistors to single type specifications. The equipment must also be adaptable to many different types of transistor specifications. To accommodate these conditions expediently, the VAST I was designed to test 20 parameters on each transistor at a rate of 3600 per hour. Rapid set-up for various types of specifications is accomplished by use of the punched card enabling a simple change of the bias conditions and test limits for each specification to be tested.

A provision is made for rapid calibration check on the tester and any mechanical failure of the equipment is automatically checked to prevent error in discrimination between rejected and accepted units.

In its present design, the VAST I automatically picks-off transistors at each test station without discriminating between failures at upper and lower parameter limits. However, a memory mechanism incorporated makes it possible to provide separate rejection and collection of units in respect to upper and lower limit failures.

The tester uses 25% of its cycle time to transfer transistors from station to station while 75% of cycle time is used for testing and collection of units into appropriate bins.

TEST MODULES

Each parameter test is controlled and facilitated by a separate test module. A test module incorporates plug-in printed circuit boards and voltage limit comparators.

Automatic programming of voltage and current bias conditions, of "go-no-go" limits, and of diode clamp voltage levels, are facilitated by relay operated resistor decades. Twelve relays and twelve fixed resistors are sufficient to program voltages from 0 to 100 volts in 0.1 volt increments. The card reader provides twelve holes for operating each group of twelve relays.

CALIBRATION CHECK SYSTEM

Calibration of VAST I is checked by a simple manual operation.

Green "go" indicator lamps and red "no-go" lamps are supplied on the front panel to indicate the decision of each voltage limit comparator. Depression of high and low limit "go" and "no-go" push buttons will illuminate all green and red lamps when each test module is properly calibrated.

The calibration check is to be made when all test sockets are empty. No circuits are broken to accomplish the check. Relay closures in each test module parallel each transistor socket under test with precision resistors. Thus, checks are also made for socket short circuits and test track and wiring as well as for accuracy of test circuits and limits. Test jacks are supplied on each test module to permit monitoring of the actual circuit conditions by use of portable meters.

SUMMARY OF TESTS

TEST	NO. OF LIMITS	PARAMETER LIMIT RANGE	VOLTAGE OR CURRENT RANGES
I_{CO}	1	.01 ua - 10 MA	0 - 100 Volts in 0.1 V steps
I_{CO}	1	.01 ua - 10 MA	0 - 100 Volts in 0.1 V steps
I_{eo}	1	.01 ua - 10 MA	0 - 100 Volts in 0.1 V steps
I_{eo}	1	.01 ua - 10 MA	0 - 100 Volts in 0.1 V steps
V_{RT}	1	1 Volt	0 - 100 Volts
BV_{CER}	1	0 to 100 Volts	0 to 100 V 10 ua to 100 ma
BV_{CES}	1	0 to 100 Volts	0 to 100 V 10 ua to 100 ma
BV_{EBO}	1	0 to 100 Volts	0 to 100 V 10 ua to 100 ma
H_{FE} (DC Beta)	2	0 to 2 V V_{CE} 0 to 2 V V_{BE}	1 ua to 100 ma base 10 ua to 300 ma
H_{FE}	2	0 to 2 V V_{CE} 0 to 2 V V_{BE}	1 ua to 100 ma base 10 ua to 300 ma
H_{FE}	2	0 to 2 V V_{CE} 0 to 2 V V_{BE}	1 ua to 100 ma base 10 ua to 300 ma
H_{FE}	2	0 to 2 V V_{CE} 0 to 2 V V_{BE}	1 ua to 100 ma base 10 ua to 300 ma
1000 Cycle Beta	2	0 to 1000	0 to 50 Volts .1 ma to 100 ma

APPLICATIONS ENGINEERING DIGESTS

APPLICATIONS ENGINEERING DIGEST NO. 63

Circle 198 on Reader Service Card

Two-Stage, Direct-Coupled 5-Watt Class-A Power Amplifier; Minneapolis-Honeywell Regulator Co., Semiconductor Products Div., Minneapolis, Minn. (J. A. Lostetter)

The circuit shown in *Fig. 63.1* utilizes a 3N47 or 3N51 tetrode power transistor in the output stage. This amplifier is capable of better than 5-watts output, with total harmonic distortion of about 1.5%.

Base 2 of the tetrode is connected to a reverse-biasing source consisting of a 6-volt supply and a 220-ohm series resistor. Base 1 is forward biased in the conventional manner with a 1000-ohm potentiometer, R_e connected to a 12-volt collector supply. The combination of these forward- and reverse-biasing networks will establish a quiescent, no-signal, collector current of 1.2 to 1.4 amperes *d-c*. The input signal is divided between the two base connections by

means of a fixed 47-ohm and a 150-ohm resistor network.

Among the units satisfactory for the driver stage is the 2N1263 power transistor, although an improved frequency response would be desirable. The driver stage employs local voltage feedback in the form of a 4.7-ohm emitter resistor and a 330-ohm resistor from the base connection to the positive 6-volt bias supply (*see Fig. 63.1*). This feedback arrangement improves the *d-c* operating point stability; improves the frequency response; reduces distortion; and permits feeding back from the output stage to the emitter of this stage.

A voltage-divider-type base bias network, consisting of a 330-ohm resistor (R_2), and a 3900-ohm resistor (R_1), connected between the positive 6-volt bias supply and the 12-volt collector supply, respectively, is used to establish a quiescent collector current of about 100 *ma d-c*.

About 6 *db* of negative loop feedback is used to match the output impedance of the amplifier to the load, and further reduce the distortion. The feedback path consists of a 270-ohm resistor connected between the collector of the output stage and the emitter of the driver stage. This path includes the emitter current of the driver stage. Because there is practically no phase shift between the emitter and collector currents of this stage in the useful passband of the amplifier, the phase shift around the feedback path is essentially that of the output stage only.

In the direct-coupled circuit shown in *Fig. 63.1*, power-type *pnp* germanium transistors are used in both stages. Their saturation currents are not greatly different. Because a phase reversal exists between the two common-emitter stages, a temperature change causes the shift in the *d-c* collector current of the driver stage to compensate for the shift in the operating point of the output stage. Consequently, the stability, or lack of stability, of the driver stage is the dominant factor in the operating-point stability of the amplifier. Actually, over-compensation exists. That is, the collector current of the output stage decreases slightly as temperature is increased.

Coupling the output stage to the load is relatively simple and straightforward. The collector of the output stage is shunt-fed through a low *d-c* resistance choke. For the collector supply voltage and quiescent current used, maximum power output is obtained with an 8- to 10-ohm load across the collector-to-emitter of the output stage. A fifty-percent reduction in power output results from 5- or 20-ohm values of load resistance. To remedy this, a tapped choke can be used to permit maximum power output into load resistance values of 4, 8, or 16 ohms.

Circuit Construction, Adjustment, and Testing Suggestions

The amplifier circuit should be constructed on an aluminum chassis with an adequate radiation and convection surface to handle the 15-watt steady-state collector dissipation of the output transistor. A chassis with approximately 150 square inches of radiation and convection surface should be satisfactory.

The areas where the output transistor, and the ripple-filter transistor are to be mounted should be reinforced with ⅛-inch aluminum to reduce localized heating. The top and bottom of the chassis should be ventilated for convection purposes.

The driver transistor should be mounted on a small (6- to 8-square-inch) auxiliary aluminum plate and located three to four inches from the output stage, making sure each transistor is electrically insulated from the chassis. The relative location of these two transistors will influence the temperature compensation of the operating point. Finishing the chassis with a coat of flat black paint will improve its radiation capabilites.

A ground bus should be used for all connections to the positive side of the 12-volt collector supply. The bus should be fastened to the chassis at one point.

If a separate 6- and 12-volt supply is used, the 6-volt supply should be turned on first when applying power to the amplifier.

To check the performance of the amplifier, a signal generator is connected to the input and its amplitude is adjusted to obtain a 20-volt peak-to-peak votlage across the 10-ohm load resistor. A list of performance figures is shown in *Fig. 63.1*.

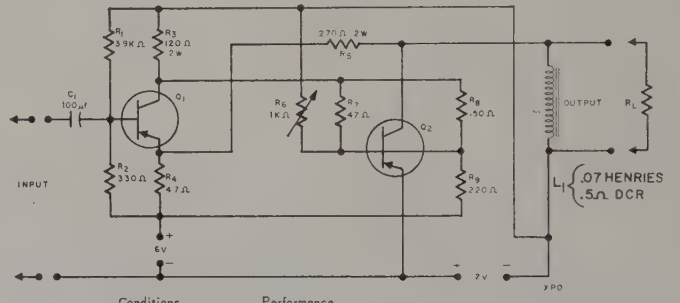


Fig. 63.1—Two-stage 5-watt power amplifier.

APPLICATIONS ENGINEERING DIGEST NO. 64

Circle 199 on Reader Service Card

A Simple Method of Measuring HF and VHF Transistor Current Gain; Fairchild Semiconductor Corp., Mountain View, Cal. (P. J. Beneteau and M. Siegel)

The block diagram (see *Fig. 64.1*) consists essentially of a constant current *a-c* source in series with a very small resistor (say 1 ohm to simulate the shorted output condition) and a parallel circuit made up of the transistor and a switch. The switch *S* is closed, and the constant-current source is set to give a reading of 1 millivolt at the output as measured on the *r-f* millivoltmeter. *S* is then opened, and the same input current as before is amplified by the transistor and goes through *R*. This voltage drop equals h_{fe} and is read directly on the *r-f* millivoltmeter. *Fig. 64.2* shows a practical circuit.

In lieu of a switch, a shorted (base-to-collector) transistor header is inserted, and the oscillator output voltage is adjusted to result in $V_{out} = 1$ *mv*. The header is removed, the transistor inserted, the *d-c* power applied, and h_{fe} is read on the meter.

Referring to *Fig. 64.3*, C_{ce} can be neglected, since it is shunted by a 1 ohm resistor. C_{bc} is a problem since it becomes equivalent to a Miller capacitance. The 1 ohm resistor may be neglected.

The next step is then to neutralize

C_{be} and C_{bc}, which are both in the order of 0.3 to 2.5 $\mu\mu f$. See *Fig. 64.4*. The *r-f* voltmeter is connected to the base through an isolating resistor R_1. R_P is the 50 ohm *r-f* probe. The method consists of adjusting C for maximum *a-c* voltage at the neutralizing output with a blank (open) transistor header in the socket to simulate lead capacitance. Then, the *r-f* voltmeter is removed and reconnected to the output. A 50 ohm termination is inserted at the neutralizing output, a shorted transistor header is inserted, and the input from the signal generator is adjusted to result in a 1 *mv* signal at the output. The test circuit is now calibrated, and transistors can now be inserted and measured for h_{fe} in quick succession.

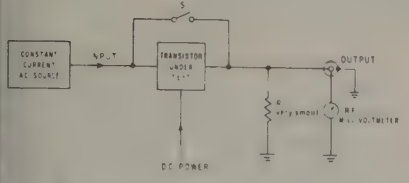


Fig. 64.1—Block diagram of h_{fe} measurement.

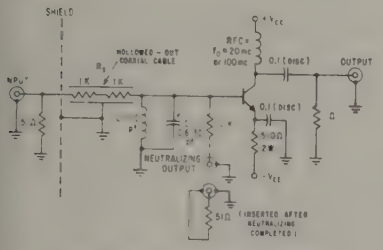


Fig. 64.2—h_{fe} test circuit.

One further precaution must be observed. At *vhf*, "end-to-end" resistor capacitance can shunt the input resistor to such an extent that a constant-current source no longer exists. For example, at 100 *mc*, a 1 $\mu\mu f$ capacitance is only 1.6 $K\Omega$ which would mean the parallel input impedance of (2 *K* in parallel with 1 $\mu\mu f$) would be reduced to 1.25 $K\Omega$. Since there are cases where the 100 *mc* input impedance of a transistor is 125 ohms or more the error in h_{fe} can be 10% or more. This can be considerably improved by using two series resistors and then shielding them with a short hollowed-out length of coaxial cable. The added parallel capacitance to ground is tuned out in the usual manner, while the shunting capacitance (from oscillator output to base) is reduced to a very low value (say 0.3 $\mu\mu f$). A further aid is to insert, at calibration, a header with a resistor connected from base to collector, rather than shorted. This resistor should be approximately the input impedance of the transistor at that frequency. Thus when the calibrating current is set up, the oscillator will see very nearly the same impedance as when the transistor is inserted, and therefore, will furnish the same input current in both cases. This precaution may not be necessary at low frequencies, but is essential in the 100 *mc* region if the reading is to be accurate within 10%.

Precautions

It should be noted that, as in any high-frequency circuit, the layout and the wiring are of the utmost importance. The input should be shielded from the output, high-frequency capacitors should be used, and even though the socket capacitances are tuned-out, it is advisable to use low-loss, low capacity teflon sockets. A copper ground plate should be used, and all components should be mounted as close to the plate as possible.

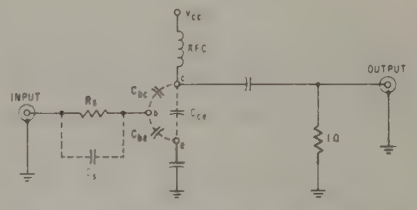


Fig. 64.3—Socket and lead capacitances.

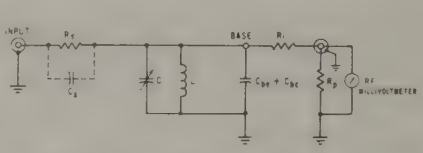


Fig. 64.4—Input circuit compensated for $C_{be} + C_{bc}$.

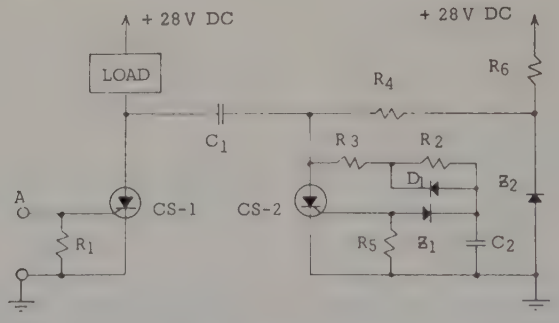
APPLICATIONS ENGINEERING DIGEST NO. 65

Circle 200 on Reader Service Card

Interval Timer for High Level Output; Solid State Products, Inc., Salem, Mass.

Fig. 65.1 shows a typical interval timing circuit designed for operation from a 28 volt *d-c* power source which provides 1 ampere to a load for 1 second. The circuit is designed for operation over the temperature range of —55 to 100°C and from 22 to 40 volts *d-c*. Complete solid-state construction assures minimum size, together with high acceleration and shock capacity.

The timing cycle is started by applying an input pulse to point *A*. A 5 microsecond or longer pulse with a minimum amplitude of 1 *V* at point *A* is required. This pulse turns on *CS-1*, which in turn supplies power to the load. At the same time, *CS-2* is turned off by the action of the commutating capacitor C_1, and timing capacitor C_2 commences to charge through R_2, R_3 and R_4. The zener diode Z_2 is used to establish a fixed charging voltage source, and minimizes timing error due to variations in the source voltage. When the charge on C_2 reaches approximately 7.5 volts, Z_1 will conduct sufficiently to cause *CS-2* to fire. This occurs one second after the initiating pulse turns off *CS-1* due to the action of commutating capacitor C_1. Power is thus removed from the load. Diode D_1 and R_3 discharge C_2 rapidly, so that total recycle time is less than 1 millisecond.



CS-1 - SSPI Type 3A60A/S Controlled Switch
CS-2 - SSPI Type 3A31 Controlled Switch

Z_1 -	6.8 volt zener diode, Type 1N710A	C_1 -	2 uf, 30 V
Z_2 -	18 volt zener diode, Type 1N720A	C_2 -	40 uf, 10 V
R_1 -	1000 ohms	R_4 -	2200 ohms
R_2 -	50,000 ohms	R_5 -	6800 ohms
R_3 -	10 ohms	R_6 -	2200 ohms
D_1 -	1N483 Silicon Diode	All Resistors - 1/4 watt	

Fig. 65.1—Interval timing circuit.

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Feb. 10, 1959 to Mar. 24, 1959. In subsequent issues, patents issued from Mar. 24, 1959 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

February 10, 1959

2,873,387 Controllable Transistor Clipping Circuit—M. C. Kidd. Assignee: RCA. Means for limiting or clipping a translated signal.

2,873,388 Pulse Counter—D. E. Trumbo. Assignee: USA (USAEC). A low power consuming counting circuit having a readily adjustable count scale.

2,873,389 Logic Circuit—W. B. Cagle, W. Ulrich. Assignee: BTL. Means of driving multiple output circuits having different input impedances, from a single logic circuit.

February 17, 1959

2,874,083 Transistor Construction—K. F. Stripp, A. R. Moore. Assignee: RCA. The process of manufacturing a device which employs low depth penetration of the emitter into the base region.

2,874,232 Transistor Element and Transistor Circuit—P. J. Jochems. Assignee: North American Philips Co. Inc. In a single device having two portions, one zone is connected as a grounded emitter.

2,874,233 Transistor Power Amplifier—J. H. Guyton, E. G. Roka. Assignee: General Motors Corp. In the apparatus described, a transistor power amplifier stage with adjustable negative feedback to compensate for the nonlinear response of the transistor is provided.

2,874,236 Semiconductor Stabilizing Apparatus—D. J. Sikorra. Assignee: Minneapolis - Honeywell Regulator Co. A multistage direct coupled semiconductor amplifier circuit with means for stabilizing operation over a wide temperature range.

2,874,293 Regulated Oscillator—I. B. McMurren. Assignee: Lear Inc. A self-regulated saturable core transistor oscillator.

2,874,311 Linear Sweep-Signal Generator —R. E. Turnage. Assignee: Hazeltine Research Inc. The circuit combines two opposite-polarity nonlinear sweep signals into a single linear sweep signal.

2,874,312 Transistor Limiter Amplifier—A. J. Radcliffe, A. R. Denz. Assignee: International Telephone & Telegraph Corp. A transistor amplifier suitable for use between a carrier transmission line and a frequency discriminator.

2,874,313 Data Processing Apparatus—J. A. Githens. Assignee: BTL. Physical arrangements of electrical circuit components to form package-type digital computer circuits.

2,874,315 Switching Device—W. G. Reichert Jr. Assignee: Allen B. DuMont Laboratories Inc. A pulse generating multivibrator circuit having low power requirements.

2,874,331 Transistorized Current Transfer Apparatus—F. B. Otto. In lighting or signaling apparatus having multiple light producing elements, means for causing current flow through one element only and means for shifting current to a second element upon failure of the first.

2,874,339 Control of Power Delivery to Electrical Apparatus—S. Perlman. Assignee: USA Dept of the Air Force. A transistored d-c power supply.

2,874,340 Rectifying Contact—K. Lehovec. Assignee: Sprague Electric Co. A rectifying contact made by placing a terminal lead in contact with a drop of mercury said drop being positioned in a concave portion of a semiconductive body, and said lead being insulated from the semiconductor.

2,874,341 Ohmic Contacts to Silicon Bodies —F. J. Biondi, H. M. Cleveland, M. J. Sullivan. Assignee: BTL. A low resistance electrode is attached to a silicon body by brazing with a brazing agent containing a suitable alloy.

February 24, 1960

2,874,448 Method for Stabilizing Semiconductor Rectifiers—W. F. Haldeman. Assignee: None. A heat treatment technique to stabilize the resistance current characteristics of semiconductor rectifiers.

2,875,103 Method of Manufacturing Selenium Rectifiers—E. L. French. Assignee: Westinghouse Brake and Signal Co. Ltd. Formation of a non-genetic barrier layer on a selenium layer by applying to the latter a solution of ethoxylene resin dissolved in benzyl alcohol.

2,875,108 Zone Melting Process—W. G. Pfann. Assignee: BTL. In a traveling zone technique, a liquid crucible is provided by a liquid-to-liquid interface between two immiscible solutions.

2,875,140 Method and Apparatus For Producing Semiconductive Structures—T. V. Sikina. Assignee: Philco Corp. The spectral distribution of light transmitted through a semiconductive body provides a measure of the thickness thereof during an etching process.

2,875,141 Method and Apparatus for Use In Forming Semiconductive Structures—R. N. Noyce. Assignee: Philco Corp. The spectral distribution and transmission of radiation through a semiconductor body is used to measure the thickness thereof during a thickness modification process.

2,875,284 Electrical Amplifying Means—R. J. Ehret. Assignee: Minneapolis-Honeywell Regulator Co. In an amplifier, means for equally dividing input current between a plurality of transistors having differences in their input impedances.

2,875,308 Photoresistive Cells—P. Tarbes. Assignee: North American Philips Co. Inc. RBV (France). Means for hermetically encasing a cadmium-sulphide photoresistive cell.

2,875,379 Gas Discharge Lamp Power Supply—G. T. Porter. Assignee: Phillips Petroleum Co. A transistor power supply for a gas discharge tube automatically reduces the magnitude of the voltage across the tube when the discharge is initiated.

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uctural and Physical Effects Impurities in Indium Arsenide	Techl Translations Nov 9 1960 Zeit fur Natur (Ger)	Order from SLA (see above) $3.30, 60-16824. The distribution coefficients and inequalities for the solubility of Mg, Zn, Cd, Si, Ge, Sn, Se and Te were determined.	E. Schillman
dy and Realization of a High- quency Furnace for the Labo- ory	Techl Translations Nov 25 1960 Il des Recherches (Fr)	Order from SLA (see above) $1.80, 60-18306. A h-f generator, 500 kc to 2 mc, selected to melt semiconductors, either in a crucible or using "regional" melting.	Y. Roux
tus of Electronics Research l Development in Communist ina (Semiconductor Devices l Transistors)	Techl Translations Nov 25 1960	Order from OTS office of Technical Services, Dept. of Commerce, Wash. 25, D.C. $0.75, 60-21919.	
ocess for Producing Extremely re Silicon for Semiconductors	Techl Translations Nov 25 1960 Pat Appl (Ger)	Order from RIS, Research Information Service, 40 E. 23 St., New York 10, N. Y. $29.75. RIS rept 97122.	
viet Solid State Physics	Techl Translations Nov 25 1960 PAL (USSR)	Order from OTS (see above) $0.50, 60-21923 Soviet experimental work is of lower calibre than U.S. in transistors but higher in thermoelectricity.	
e Use of Quartz Crystal Oscil- ors in Weighing Thin Film and Microweighing	Techl Translations Nov 25 1960 Zeit fur Phys (W Ger)	Order from SLA (see above) $3.30, 60-18069.	G. Sauerbrey
licon Photocells	Techl Translations Nov 25 1960 Siemens Zeit (W Ger)	Order from SLA (see above) $3.30, 60-16662. The principles, construction, and electrical properties of Si photocells are described.	R. Wiesner F. Nissl
icrowave Solid-State Devices	US Govt Res Repts Nov 18 1960 LC $6.30 PB149016	Low temperature noise measurements on a diffused germanium varactor have been obtained for amplification in the degenerate mode at a frequency of 6 kmc/sec.	Bell Tel. Labs. Inc.
icrowave Solid-State Devices	US Govt Res Repts Nov 18 1960 LC $4.80 PB149017	Starting with a four terminal network representation, the impedance transformation from the semiconductor region of a mesa diode to a transmission line is discussed.	Bell Tel. Labs. Inc.
NP Drift Base Power Transistor	US Govt Res Repts Nov 18 1960 LC $18.30 PB149117	The production refinement program is presented for the 2N1430 drift base power transistor.	C. Z. Leinkram H. Newman W. C. Waldron
Transistor Regulated Power pply for a High Current Mag- t	US Govt Res Repts Nov 18 1960 LC $6.30 PB148179	A sampling voltage, obtained from a sensing resistor in series with the magnet is compared with a reference voltage; the error signal is amplified and fed back to the series transistor thru a 2-state transistor driver.	K. C. Brog
esearch On New High Tempera- re Semiconducting Materials	US Govt Res Repts Nov 18 1960 OTS $3.00 PB161938	Three years of research on the preparation, purification, crystal growth, and measurement of the fundamental properties of CdS, CdSe, ZnTe, and mixed crystals of CdS-CdSe are summarized.	S. S. Devlin J. M. Jost L. R. Shiozawa
heory of Switching	US Govt Res Repts Nov 18 1960 LC $30.30 PB147384	The synthesis of a special class of switching functions; silicon carbide crystal switches, and other topics are discussed.	H. Aiken
orage Light Intensifier Display nel	US Govt Res Repts Nov 18 1960 LC $4.80 PB149366	Progress is reported for work accomplished on complex circuit optical feedback light intensifiers for feedback control and multitone storage.	E. E. Loebner H. O. Hook D. C. Darling
ansistor D-C Regulators	US Govt Res Repts Nov 18 1960	Modifications and extensions of a basic series type regulator circuit are utilized in the design of three d-c regulators for electrochemical power supplies.	F. Allen H. J. Reed
ermanium PNP or NPN Junc- on Transistor	US Govt Res Repts Nov 18 1960 LC $3.00 PB149372	The necessary techniques for electrochemically etching and plating large area etch pits and electrodes on diffused germanium material have been developed; and large area, microalloyed, diffused-base transistors have been fabricated.	J. A. Sluss, Jr.
ermanium PNP or NPN Junc- on Transistor	US Govt Res Repts Nov 18 1960 LC $4.80 PB149373	An increased yield in the accurate placement of the emitter diode was the result of a modification of the gradient of diffusion in the base material.	J. A. Sluss, Jr.
uclear Radiation Resistant wer Transistors	US Govt Res Repts Nov 18 1960 LC $4.80 PB149376	Collector-to-header soldering was causing BV_{CBO} degradation. Through extensive experimentation with heating techniques, solder composition, and type of electrode, this problem and others have been eliminated.	A. Byer
ltier Effect and Thermal Con- ctivity Measurement Tech- ques For Thermoelectric Mate- als	US Govt Res Repts Nov 18 1960 LC $21.30 PB148068	This selective bibliography covers the period 1950-1958. The literature of particular interest is that of the Peltier, Seebeck, and Joule-Thompson Effects as well as certain studies of thermal conductivity.	K. D. Carroll
Binary Counter And Accumu- tor Using Transistor And Mag- tic Cores	US Govt Res Repts Nov 18 1960 LC $4.80 PB147565	Binary devices are described which employ a transistor-magnetic core combination as a fundamental building block for digital circuits.	H. R. Irons

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Regulated Linear Transformer-Rectifier Power Supplies	US Govt Res Repts Nov 18 1960 LC $3.30 PB146392	The NRL unit described in this report, without using any filtering components, has an essentially linear input impedance per phase, is relatively light, economical, and has equal if not superior regulation characteristics.	D. S. Toffolo
Parametric Amplification	US Govt Res Repts Nov 18 1960 LC $9.30 PB149166	This research was concerned with the capabilities and limitations of parametric amplifiers of the nonlinear capacitance type.	M. O. Thurston
Investigation of Physical Limitations On Current Gain (Beta) And Research On Improved Silicon Contacts	US Govt Res Repts Nov 18 1960 LC $4.80 PB148553	This report comprises two principal studies: an investigation of the factors limiting the grounded emitter current gain (B) of a transistor, and research on improved contacts for silicon.	I. Maissel P. Spratt
Micro-Module Production Program	US Govt Res Repts Nov 18 1960 LC $33.30 PB149375	The process of molybdenum-manganese metallizing combined with ultrasonically assisted soldering was adopted as a method for producing reliable hermetic seals of semiconductor and quartz crystal units.	RCA Elecncs Prod
Micro-Module Production Program	US Govt Res Repts Nov 18 1960 OTS $3.00 PB161911	Electrical testing of prototype microelements was substantially completed during this quarter, and environmental and life tests were initiated.	RCA Elecncs Prod
Transistorized Gyro Magnetic Compass Set	US Govt Res Repts Nov 18 1960 LC $7.80 PB149023	Design plans for four Gyro Magnetic Compass Sets were completed and submitted.	Sperry Gyroscope Co.
Development Of Power Transistor Circuitry	US Govt Res Repts Nov 18 1960 LC $12.30 PB149014	The use of a simple transistor push-pull oscillator circuit as a d-c to d-c power converter has been investigated.	R. R. Smyth
Thermoelectric Phenomena	US Govt Res Repts Nov 18 1960 LC $7.80 PB148969	History and applications; a physical picture using energy level diagrams, and references to materials that appear most promising.	A. D. Johnson
Thin Film Evaporation Techniques	US Govt Res Repts Nov 18 1960 LC $3.30 PB148969	A description is given of the evaporating techniques and a discussion of the system is presented.	I. Berman
Excess Noise in Semiconductors	US Govt Res Repts Nov 18 1960 LC $13.80 PB149505	Random electrical noise phenomena in solids was studied to understand the origin of 1/f noise in ZnO and to apply noise measurements to the problem of trapping transitions and neutral energy transport in cadmium sulfide.	J. J. Brophy
The Study Of Properties Of Single CdS and ZnS Crystals for Use As Detectors in Crystal Counters	US Govt Res Repts Nov 18 1960 LC $6.30 PB149503	Progress is reported on the growing of single CdS and ZnS crystals. A new technique in powder preparation has produced single crystals of greater purity.	S. J. Czyzak H. Payne et al
Mobility of An Electron In The Donor Impurity Band Of A Compensated Semiconductor	US Govt Res Repts Nov 18 1960 LC $4.80 PB 146454	The motion of an electron is studied in an aperiodic one-dimensional potential consisting of a random linear array of attractive delta-function potentials of equal strength.	A. A. Maradudin B. S. Gourary
Transmission Line Formulation For Semiconductors	US Govt Res Repts Nov 18 1960 LC $4.80 PB 146454	A calculation of two points in the band structure of lithium is tabulated with the aid of the new formulae for structure constants.	H. Kurss
Research On Photoconductive Films Of The Lead Salts	US Govt Res Repts Nov 18 1960 LC $7.80 PB147227	A review is given of recent research on the photoconductive process in lead salt films.	R. L. Petritz J. N. Humphrey
Study Of The Mechanism Of Endothermic Reactions Photosensitized On Solid Surfaces	US Govt Res Repts Nov 18 1960 LC $4.80 PB149260	Samples of CdS, CdSe, and CdTe were prepared. The light-absorbing properties of the solids were determined by reflectance measurements.	J. G. Calvert
Investigation of Physical Properties Of Semiconductors	US Govt Res Repts Nov 18 1960 OTS $1.50 PB161903	Part of the research effort described in this report was devoted to the investigation of materials which may have interesting semiconducting properties at high temperatures.	M. C. Caspari
Silicon Crystal Perfection Study	US Govt Res Repts Nov 18 1960 LC $4.80 PB149110	Single crystals of Si have been pulled from a quartz crucible heated by a regulated carbon resistance furnace in either a He or A atmosphere. A small dislocation-free seed was used with (111) grown axis.	H. U. Yearian
Studies Of Microplasmas and High-Field Effects on Silicon	US Govt Res Repts Nov 18 1960 LC $6.30 PB149411	This study is concerned with producing a p-n junction device for obtaining high internal fields perpendicular to a silicon surface.	Stanford Elecncs Labs

SEMICONDUCTOR DIODE SOURCE BOOK

WATCH FOR ANNOUNCEMENT

CHARACTERISTICS CHART of NEW TRANSISTORS

MANUFACTURERS

(In Order of Code Letters)

ARA— Advanced Research Associates, Inc.
AEG— Allgemeine Elecktricitats-gesellschaft
AMP— Amperex Electronic Corp.
AEIE— Associated Electrical Industries Ediswan Div.
AEIL— Associated Electrical Industries Export
ATLB— Associated Transistors Ltd.
BEN— Bendix Corp.
CBS— CBS Electronics
CDLF— Compagnie des Lampes
CSF— Compagnie Generale
CRY— Crystalonics, Inc.
CTP— Clevite Transistor Products, Inc.
DEL— Delco Radio Div., General Motors Corp.
ELE— Electromation Co.
ETC— Electronic Transistor Corp.
FSC— Fairchild Semiconductor Corp.
FTHF— French Thompson-Houston Semiconductor Dept.
GECB— General Electric Co., Ltd.
GE— General Electric Co.
GIC— General Instrument Corp.
GEM— Great Eastern Mfg. Co.
HITJ— Hitachi Ltd., Mushashi Works
HIVB— Hivac Ltd.
HSD— Hoffman Semiconductor Div.
HUG— Hughes Aircraft Co.
IND— Industro Transistor Corp.
INTG— Intermetall
KSC— Kearfott Semiconductor Corp.
KOKJ— Kobe Kogyo Corp.
LCTF— Labortoire Central de Telecommunications
MIN— Minneapolis-Honeywell Regulator Co.
MISI— Mistral
MOT— Motorola, Inc.
MUL— Mullard Ltd.
NAC— National Semiconductor Corp.
NTLB— Newmarket Transistors Ltd.
NECJ Nippon Electric Co. Ltd.
PSI— Pacific Semiconductors. Inc.
PHI— Philco Corp., Lansdale Division, Semiconductor Operations
RAY— Raytheon Co.
RCA— Radio Corp. of America, Semiconductor Div.
RDR— Radio Development and Research
RADF— La Radiotechnique, Div. Tubes Electroniques
RHE— Rheem Semiconductor Corp.
ROSG— Dr. ing. Rudolph Rost
SANJ— Sanyo Electric Co. Ltd.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SGSI— Societa General Semiconduttori
SONY— Sony Corp.
SPE— Sperry Rand Corporation
SPR— Sprague Electric Co.
STCB— Standard Telephone & Cables, Ltd.
STCA— Standard Telephones and Cables Pty, Ltd.
TKAD— Suddeutsche Telefon-Apparate-, Kabel und Drahtwerke
SYL— Sylvania Electric Products Inc.
TOSJ— Tokyo Shibaura Electric Co.
TRA— Transitron Electronic Corp.
TFKG— Telefunken Ltd.
TI— Texas Instruments Incorporated
TIIB— Texas Instruments Ltd.
TUN— Tung-Sol Electric, Inc.
UST— U. S. Transistor Corp.
WEC— Western Electric Co., Inc.
WTC— Western Transistor Corp.
WEST— Westinghouse Electric Corp.

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C.				Typical Characteristics			MFR. See Code
				P_C (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha b}$ (mc)	GAIN PARAMETER And (Condition)	GAIN VALUE	
2N389A	3	D	Si	85	2.04	60	60	2.0	h_{FE}:I_C-1.0A	25	SIL
2N424A	3	D	Si	85	2.04	80	80	2.0	h_{FE}:I_C-1.0A	25	SIL
2N781	5	PNP	Ge	150	500	15	15		h_{FE}:I_C- 10ma	25	SYL
2N782	5	PNP	Ge	150	500	12	12		h_{FE}:I_C- 10ma	20	SYL
2N783	5	NPN	Si	300	500	40	20		h_{FE}:I_C- 10ma	20-60	SYL
2N784	5	NPN	Si	300	500	30	15		h_{FE}:I_C- 10ma	25min	SYL
2N869	2,4,5	PNPPL	Si	1.8W	97.3Ø	25	25	100†Ø	h_{FE}:I_C- 10ma	Ø	FSC
2N909	2,4,5	NPND	Si	1.5W	100Ø	60	30	50†Ø	h_{FE}:I_C- 50ma	Ø	FSC
2N910	2,4,5,6	NPNPL	Si	1.8W	97.3Ø	100	80		h_{fe}:I_c-1.0ma	100	FSC
2N911	2,4,5,6	NPNPL	Si	1.8W	97.3Ø	100	80		h_{fe}:I_c-1.0ma	50	FSC
2N912	2,4,5,6	NPNPL	Si	1.8W	97.3Ø	100	80		h_{fe}:I_c-1.0ma	30	FSC
2N914	2,3,4,5,6,9	NPNPL-E	Si	1.2W	145Ø	40	20	300†Ø	h_{FE}:I_C- 10ma	Ø	FSC
2N915	2,4,5	NPNPL	Si	1.2W	145Ø	70	50	250†Ø	h_{FE}:I_C- 10ma	Ø	FSC
2N916	2,4,5	NPNPL	Si	1.2W	145Ø	45	25	300†Ø	h_{FE}:I_C- 10ma	Ø	FSC
2N917	4,5,9	NPNPL	Si	300W	583Ø	30	15	800Ø	h_{FE}:I_C-3.0ma	Ø	FSC
2N919	5	NPNMe	Si	1200	145	25	15		h_{FE}:I_C- 10ma	40	PSI
2N920	5	NPNMe	Si	1200	145	25	15		h_{FE}:I_C- 10ma	80	PSI
2N921	5	NPNMe	Si	1200	145	50	30		h_{FE}:I_C- 10ma	40	PSI
2N922	5	NPNMe	Si	1200	145	50	30		h_{FE}:I_C- 10ma	80	PSI
2N923	1	PNPA	Si	150	1150	40	25	1.2	h_{fe}:I_c-1.0ma	20	NAC
2N924	1	PNPA	Si	150	1150	40	25	1.2	h_{fe}:I_c-1.0ma	40	NAC
2N925	1	PNPA	Si	150	1150	50	40	1.0	h_{fe}:I_c-1.0ma	15	NAC
2N926	1	PNPA	Si	150	1150	50	40	1.0	h_{fe}:I_c-1.0ma	35	NAC
2N927	1	PNPA	Si	150	1150	70	60	1.0	h_{fe}:I_c-1.0ma	15	NAC
2N928	1	PNPA	Si	150	1150	70	60	1.0	h_{fe}:I_c-1.0ma	30	NAC
2N1768	5	NPND	Si	40W	4.35	60	60	1.25	h_{FE}:I_C-750ma	35-100	RCA
2N1769	5	NPND	Si	40W	4.35	100	100	1.25	h_{FE}:I_C-750ma	25-100	RCA

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C.				Typical Characteristics			MFR. See Code
				P_C (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha b}$ (mc)	GAIN PARAMETER And (Condition)	GAIN VALUE	
2SC31	4	NPND	Si	1.5W		60	25	230	PG at 30Mc	18db	NECJ
2SC32	4	NPND	Si	1.5W		60	25	280	PG at 30Mc	19db	NECJ
10T2	2	NPN	Si	125		30	30	10	h_{FE}:I_C-1.0ma	31	FTHF
11T2	2	NPN	Si	125		30	30	10	h_{FE}:I_C-1.0ma	63	FTHF
12T2	2	NPN	Si	125		30	30	10	h_{FE}:I_C-1.0ma	100	FTHF
17T1	3	PNP	Ge	550		35			h_{FE}:I_C- 20ma	100	FTHF
18T1	3	PNP	Ge	550		25			h_{FE}:I_C- 20ma	100	FTHF
38T1	2	PNP	Ge	90		20	14	10	h_{FE}:I_C- 10ma	50	FTHF
39T1	2	PNP	Ge	90		14	10	15	h_{FE}:I_C- 10ma	100	FTHF
C610	1,2,4,5	FLD	Si	250	540	40	40	5.0	Gm(uA/V) at 24V	250	CRY
C611	1,2,4,5	FLD	Si	250	540	40	40	5.0	Gm(uA/V) at 24V	400	CRY
C612	1,2,4,5	FLD	Si	250	540	40	40	5.0	Gm(uA/V) at 24V	650	CRY
C613	1,2,4,5	FLD	Si	250	540	40	40	5.0	Gm(uA/V) at 24V	1000	CRY
C614	1,2,4,5	FLD	Si	250	540	40	40	5.0	Gm(uA/V) at 24V	250	CRY
C615	1,2,4,5	FLD	Si	250	540	40	40	5.0	Gm(uA/V) at 24V	750	CRY
C650	5	FLD	Si	250	540	40	40	5.0			CRY
C651	5	FLD	Si	250	540	40	40	5.0			CRY
C652	5	FLD	Si	250	540	40	40	5.0			CRY
C653	5	FLD	Si	250	540	40	40	5.0			CRY
GFT42A	2,4	PNPD	Ge	50	1000	15	10	60Ø	PG at I_e-1ma	7.5db	TKAD
GFT42B	2,4	PNPD	Ge	50	1000	15	10	60Ø	PG at I_e-1ma	12db	TKAD
GFT43A	2,4	PNPD	Ge	50	1000	15	10	30Ø	PG at I_e-1ma	26db	TKAD
GFT43B	2,4	PNPD	Ge	50	1000	15	10	10Ø	PG at I_e-1ma	55db	TKAD
KGS1004	5	PNPA	Ge	200	.35	10	7.0	25Ø	h_{fe}:I_b-1.0ma	70min	KSC
KGS1005	5	PNPA	Ge	200	.35	30		5.0	h_{fe}:I_c-150ma	40	KSC
FT600	5Ø	NPNMe	Si	13W	11.5	60	45		h_{FE}:I_C-1.0A	30	PSI
[illegible]	5Ø	NPNMe	Si	[illegible]		[illegible]	45		[illegible]	[illegible]	[illegible]

TYPE NO.	See Code Below	See Code Below	MAT	P_C (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha b}$ (mc)	PARAMETER And (Condition)	VALUE	MFR. See Code
2N1902	5	NPNMe	Si	125W	1.0	140	100		h_{FE}:I_C- 10A	37	PSI
2N1903	5	NPNMe	Si	125W	1.0	140	100		h_{FE}:I_C- 10A	15	PSI
2N1904	5	NPNMe	Si	125W	1.0	140	100		h_{FE}:I_C- 10A	27.5	PSI
2N1958	5	NPN	Si	600	250	60	40		h_{FE}:I_C-150ma	20-60	SYL
2N1959	5	NPN	Si	600	250	60	40		h_{FE}:I_C-150ma	40-120	SYL
2N1960	5	PNP	Ge	150	500	15	15		h_{FE}:I_C- 10ma	25	SYL
2N1961	5	PNP	Ge	150	500	12	12		h_{FE}:I_C- 10ma	20	SYL
2N1962	5	NPN	Si	400	375	40	20		h_{FE}:I_C- 10ma	20-60	SYL
2N1963	5	NPN	Si	400	375	30	15		h_{FE}:I_C- 10ma	25min	SYL
2N1964	5	NPN	Si	400	375	60	40		h_{FE}:I_C-150ma	20-60	SYL
2N1965	5	NPN	Si	400	375	60	40		h_{FE}:I_C-150ma	40-120	SYL
2N1966	5	PNPNA	Ge	120	420	35	35		I_B(ON) -.50ma, I_{CS}-20ma max		TUN
2N1967	5	PNPNA	Ge	120	420	35	35		I_B(ON) -.50ma max, I_{CS}-20-80ma		TUN
2N1968	5	NPNPA	Ge	120	420	35	18		I_B(ON) -.30ma max, I_{CS}-5ma max		TUN
2N1969	5	PNP	Ge	150	566	30	15	10	h_{FE}:I_B-.20ma	80-200	SYL
2N1970	3	A	Ge		.50	100	50		h_{FE}:I_C-5.0A	17-40	DEL
2N1971	3	A	Ge		2.0	80	40		h_{FE}:I_C-.50A	25-60	DEL
2N1972	2,4,5	NPND	Si	2.0W	75Ø	60	30	50†	h_{FE}:I_C- 50ma	Ø	FSC
2N1973	2,4,5,6	NPNPL	Si	3.0W	58.3Ø	100	80		h_{fe}:I_C-1.0ma	100	FSC
2N1974	2,4,5,6	NPNPL	Si	3.0W	58.3Ø	100	80		h_{fe}:I_C-1.0ma	50	FSC
2N1975	2,4,5,6	NPNPL	Si	3.0W	58.3Ø	100	80		h_{fe}:I_C-1.0ma	30	FSC
2N1978	3,4,5,9	NPNPL	Si	30W	5.83Ø	60	40	40†	h_{FE}:I_C-500ma	Ø	FSC
2N1983	2,4,5	NPND	Si	2.0W	62.5Ø	50	25		h_{fe}:I_C-1.0ma	90	FSC
2N1984	2,4,5	NPND	Si	2.0W	62.5Ø	50	25		h_{fe}:I_C-1.0ma	45	FSC
2N1985	2,4,5	NPND	Si	2.0W	62.5Ø	50	25		h_{fe}:I_C-1.0ma	25	FSC
2N1986	2,4,5	NPND	Si	2.0W	62.5Ø	50	30	50†	h_{FE}:I_C-150ma	150Ø	FSC
2N1987	2,4,5	NPND	Si	2.0W	62.5Ø	50	30	50†	h_{FE}:I_C-150ma	50Ø	FSC
2N1988	2,4,5	NPND	Si	2.0W	62.5Ø	100	60	50†	h_{FE}:I_C- 30ma	65Ø	FSC
2N1989	2,4,5	NPND	Si	2.0W	62.5Ø	100	60	50†	h_{FE}:I_C- 30ma	40Ø	FSC
2N1990	2,4,5	NPND	Si	2.0W	62.5Ø	100			h_{FE}:I_C- 30ma	Ø	FSC
2N1991	2,4,5	PNPD	Si	2.0W	62.5Ø	30	20	50†	h_{FE}:I_C-150ma	35Ø	FSC
2SA244	4	PNPD	Ge	200		25	20	600	PG at 100Mc	12.5db	NECJ
2SA245	4	PNPD	Ge	200		25	20	700	PG at 100Mc	14.5db	NECJ
2SB238	3	PNPA	Ge	13W	5.0	40	30	.50	h_{FE}:I_C-500ma	60	NECJ
2SB239	3	PNPA	Ge	13W	5.0	80	45	.50	h_{FE}:I_C-500ma	60	NECJ
2SB240	3	PNPA	Ge	13W	5.0	40	30	.50	h_{FE}:I_C-500ma	60	NECJ
2SB240A	3	PNPA	Ge	13W	5.0	60	40	.50	h_{FE}:I_C-500ma	60	NECJ
2SB241	3	PNPA	Ge	13W	5.0	80	45	.50	h_{FE}:I_C-500ma	60	NECJ
2SB241A	3	PNPA	Ge	13W	5.0	100	50	.50	h_{FE}:I_C-500ma	60	NECJ
2SB242	3	PNPA	Ge	13W	5.0	30	20	.50	h_{FE}:I_C-500ma	40	NECJ
2SB242A	3	PNPA	Ge	13W	5.0	60	30	.50	h_{FE}:I_C-500ma	40	NECJ
2SB243	3	PNPA	Ge	13W	5.0	30	20	.50	h_{FE}:I_C-500ma	90	NECJ
2SB243A	3	PNPA	Ge	13W	5.0	60	30	.50	h_{FE}:I_C-500ma	90	NECJ
2SB244	3	PNPA	Ge	13W	5.0	80	40	.50	h_{FE}:I_C-500ma	40	NECJ
2SB245	3	PNPA	Ge	13W	5.0	80	40	.50	h_{FE}:I_C-500ma	90	NECJ
2SB246	3	PNPA	Ge	54W	1.2	40	25	.35	h_{FE}:I_C-3.0A	60	NECJ
2SB247	3	PNPA	Ge	54W	1.2	60	35	.35	h_{FE}:I_C-3.0A	60	NECJ
2SB248	3	PNPA	Ge	54W	1.2	40	25	.35	h_{FE}:I_C-3.0A	60	NECJ
2SB248A	3	PNPA	Ge	54W	1.2	60	35	.35	h_{FE}:I_C-3.0A	60	NECJ
2SB249	3	PNPA	Ge	54W	1.2	80	40	.35	h_{FE}:I_C-3.0A	60	NECJ
2SB250	3	PNPA	Ge	54W	1.2	30	20	.35	h_{FE}:I_C-3.0A	60	NECJ
2SB250A	3	PNPA	Ge	54W	1.2	60	40	.35	h_{FE}:I_C-3.0A	60	NECJ
2SB251	3	PNPA	Ge	54W	1.2	30	20	.35	h_{FE}:I_C-3.0A	40	NECJ
2SB251A	3	PNPA	Ge	54W	1.2	60	40	.35	h_{FE}:I_C-3.0A	40	NECJ
2SB252	3	PNPA	Ge	54W	1.2	80	50	.35	h_{FE}:I_C-3.0A	60	NECJ
2SB252A	3	PNPA	Ge	54W	1.2	120	80	.35	h_{FE}:I_C-3.0A	60	NECJ
2SB253	3	PNPA	Ge	54W	1.2	80	50	.35	h_{FE}:I_C-3.0A	40	NECJ
2SB253A	3	PNPA	Ge	54W	1.2	120	80	.35	h_{FE}:I_C-3.0A	60	NECJ
2SB254	3	PNPA	Ge	4000	12.5	35	35		h_{FE}:I_C-200ma	100	SANJ
2SB255	3	PNPA	Ge	4000	12.5	35	35		h_{FE}:I_C-200ma	50	SANJ
2SB256	3	PNPA	Ge	4000	12.5	25	25		h_{FE}:I_C-200ma	75	SANJ

TYPE NO.	See Code Below	See Code Below	MAT	P_C (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha b}$ (mc)	PARAMETER And (Condition)	VALUE	MFR. See Code
SFT228	4	PNPA	Ge	150	400	24	12	10#	h_{fe}:I_C-1.0ma	100	CSF
SFT238	3	PNPA	Ge	35W	2.0Ø	40	30	.30	h_{FE}:I_C-5.0A	30	CSF
SFT239	3	PNPA	Ge	35W	2.0Ø	60	40	.30	h_{FE}:I_C-5.0A	30	CSF
SFT240	3	PNPA	Ge	35W	2.0Ø	80	60	.30	h_{FE}:I_C-5.0A	30	CSF
SFT242	2	PNPA	Ge	225	270	45	20		h_{FE}:I_C-100ma	60	CSF
SFT243	2	PNPA	Ge	225	270	60	30		h_{FE}:I_C-100ma	60	CSF
SFT244	2	PNPA	Ge	225	270	80	30		h_{FE}:I_C-100ma	40	CSF
SFT245	2	PNPA	Ge	225	270	100	30		h_{FE}:I_C-100ma	40	CSF
SFT265	3	PNPA	Ge	70W	1.0Ø	40	40	.30	h_{FE}:I_C- 12A	20	CSF
SFT266	3	PNPA	Ge	70W	1.0Ø	60	50	.30	h_{FE}:I_C- 12A	20	CSF
SFT267	3	PNPA	Ge	70W	1.0Ø	80	60	.30	h_{FE}:I_C- 12A	20	CSF
SFT315	4	PNPD	Ge	150	400	40	20	30#	h_{fe}:I_C-1.0ma	80	CSF
SFT317	4	PNPD	Ge	150	400	20		40#	h_{fe}:I_C-1.0ma	100	CSF
SFT319	4	PNPD	Ge	150	400	20		30#	h_{fe}:I_C-1.0ma	40	CSF
SFT320	4	PNPD	Ge	150	400	20		35#	h_{fe}:I_C-1.0ma	80	CSF
SFT321	2	PNPA	Ge	200	300	24		1.3	h_{FE}:I_C-100ma	30	CSF
SFT322	2	PNPA	Ge	200	300	24		1.6	h_{FE}:I_C-100ma	50	CSF
SFT323	2	PNPA	Ge	200	300	24		2.6	h_{FE}:I_C-100ma	85	CSF
SFT351	2	PNPA	Ge	200	300	24		1.2	h_{fe}:I_C-1.0ma	30	CSF
SFT352	2	PNPA	Ge	200	300	24		1.6	h_{fe}:I_C-1.0ma	50	CSF
SFT353	2	PNPA	Ge	200	300	24		2.4	h_{fe}:I_C-1.0ma	80	CSF
SFT354	4	PNPD	Ge	120	500	20		55#	h_{fe}:I_C-1.0ma	100	CSF
SFT357	4	PNPD	Ge	120	500	20		70#	h_{fe}:I_C-1.0ma	100	CSF
TK201A	3,5	D	Si	2500		40	20	100†			STCB
TK250A	2,5	D	Si	500		40	20	100†			STCB
TK251A	2,5	D	Si	500		40	20	100†			STCB

NOTATIONS

Under Use

1- Low power a-f equal to or less than 50 mw
2- Medium power a-f 50 mw and equal to or less than 500 mw
3- Power>500 mw
4- r-f/i-f
5- Switching and Computer
6- Low Noise
7- Photo
8- Mixer
9- Local Oscillator
Ø- Revised Spec.
10- Chopper
11- Matched Pair
12- Video Amplifier
13- TV Sync. Separator
FLD—Field Effect

Under Type

A- Alloyed
D- Diffused or Drift
E- Epitaxial Mesa
F- Fused
G- Grown
H- Hook Collector
M- Microalloy
PL- Planar
Me- Mesa
O- Other
S- Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
§ Tetrode

Under Gain Value

Ø- Pulsed

Under fab

* — Maximum Frequency
# — Figure of Merit
Δ — $f_{\alpha e}$
Ø — Minimum
+ — f_T (Gain Bandwidth Product)
Ø — f_{os} max. (Max. freq. of oscillation)

Under Derating

Ø- Infinite heat sink

PREVIOUSLY REGISTERED NEWLY ANNOUNCED TRANSISTORS

CBS ELECTRONICS: 2N128, 2N174A, 2N232, 2N240, 2N344, 2N345, 2N346, 2N1122, 2N1122A, 2N1358, 2N1411, 2N1412, 2N1427

COSEM: 2N384, 2N524, 2N525, 2N526, 2N527, 2N1225

DELCO RADIO DIVISION: 2N456A, 2N457A, 2N458A, 2N669, 2N1021, 2N1022, 2N1534, 2N1535, 2N1536, 2N1537

FRENCH THOMPSON-HOUSTON SEMICONDUCTOR: 2N377, 2N441, 2N696, 2N717, 2N1208, 2N1209, 2N1212, 2N1671, 2N1671A, 2N1671B, 3N34, 3N35

KEARFOTT SEMICONDUCTOR: 2N394 thru 2N397, 2N396A, 2N414A, 2N414B, 2N417, 2N519 thru 2N523, 2N519A thru 2N523A, 2N1017, 2N1018, 2N1307, 2N1309

MOTOROLA SEMICONDUCTOR: 2N174A, 2N398, 2N702, 2N703, 2N707, 2N707A, 2N753, 2N1412

NATIONAL SEMICONDUCTOR: 2N706, 2N706A, 2N706B

PACIFIC SEMICONDUCTOR: 2N701, 2N702, 2N703, 2N707, 2N743, 2N744, 2N834

RCA: 2N705, 2N710, 2N711

SILCON TRANSISTOR: 2N1210, 2N1211, 2N1620, 2N1700, 2N1701, 2N1767, 2N1768

SYLVANIA: 2N706, 2N706A, 2N706B, 2N706C, 2N743, 2N744, 2N828

WESTERN TRANSISTOR: 2N327A, 2N328A, 2N329A, 2N1229, 2N1234

Industry News . . .

CONFERENCE CALENDAR

The Following June 1961 Meetings Are Scheduled:

June 5- 7 15th Annual Convention, Armed Forces Communications & Electronic Association, Wash., D. C.

June 6- 8 ISA Summer Instrument-Automation Conference & Exhibit, Royal York Hotel, Queen Elizabeth Hall, Toronto, Ont., Canada. For Information: Wm. H. Kushnick, ISA, Penn Sheraton Hotel, 530 Wm. Penn Place, Pittsburgh 19, Pa.

June 14-15 5th National Conference on Product Engineering and Production, Sheraton Hotel, Phila. Sponsored by PGPEP. For Information: John A. Knoll, RCA Surface Comm. Eng., Location 1-4, Camden, N. J.

June 18-23 Summer Meeting AIEE, Cornell University & Statler Hotel, Ithaca, N. Y. For Information: Prof. Wm. H. Erickson, Elec'l Engineering, Cornell University, Ithaca, N. Y.

June 22-24 American Physical Society, Mexico City.

June 26-27 5th Annual Conference of Vacuum Metallurgy, New York University, University Heights Campus, Bronx, N. Y. Sponsored by American Vacuum Society & NYU.

June 25-30 Annual Meeting, American Society for Testing Materials, Chalfonte-Haddon Hall, Atlantic City, N. J. For Information: ASTM, 1916 Race Street, Phila. 3, Pa.

June 26-28 5th National Convention on Military Electronics, Shoreham Hotel, Wash., D. C. Sponsored by PGMIL. For Information: Harry Davis, SAFRD, Pentagon, Wash. 25, D. C.

June 28-30 Joint Automatic Control Conference, University of Colorado, Boulder, Colo. Sponsored by PGAC, ISA, AIEE, AICHE, ASME. For Information: Dr. Robt. Kramer, Elec. Systems Lab., MIT, Cambridge 39, Mass.

The University of Michigan is offering 2 Intensive Courses for Engineers and Scientists this summer: Semiconductor Theory and Technology June 19-30; Advanced Topics on Solid State Masers July 24-28. Write to Engineering Summer Conferences, 126 West Engineering Building, The University of Michigan, Ann Arbor, Michigan for application and folder giving full details.

Dr. Jerome B. Wiesner, President Kennedy's special assistant for science and technology, was named by the Electronic Industries Association board of directors for award of the 1961 EIA Medal of Honor for "distinguished service contributing to the advancement of the electronics industry." Dr. Wiesner is the first government official to be selected for the award since its establishment in 1952. Dr. Wiesner is now on leave as director of the Research Laboratory of Electronics at the Massachusetts Institute of Technology and was, until his appointment to the White House post, a director of the Sprague Electric Co.

Izvestia, March 21, reports that A. F. Ioffe's "Theoretical and Experimental Studies of Semiconductor Physics" has been nominated for the 1961 Lenin Prize. Ioffe is famous for his studies of photoelectric, optical and thermal properties of semiconductor compounds.

On the basis of experimental data he and his colleagues formulated a comprehensive theory of thermoelectric transformers. It is set forth in his monograph "Theory of Semiconductor Thermoelectric Batteries."

His last work, "Semiconductor Thermals," was translated into many languages. Ioffe's theory is a valuable tool in the hands of physicists and engineers designing new types of thermoelectric devices and presents them with a clear perspective for work on the firm basis of calculations.

Scores of semiconductor refrigerating and current generating devices have been designed on the basis of his theory.

RESEARCH AND DEVELOPMENT

Monsanto Chemical Company recently displayed samples of single crystal gallium arsenide produced by all three major crystal growing techniques, float zone refining, the gradient freeze method and the Czochralski technique.

Dr. R. A. Staniforth, Assistant Director of Development, states that at present there is no reason to believe that any one of these techniques will provide suitable material for all of the various electronic devices. For example, the float zone technique offers the best method of obtaining a really high purity material, the Czochralski method produces material with the lowest dislocation densities, and the gradient freeze technique allows the highest doping levels. Monsanto offers this single crystal gallium arsenide with mobilities of 3000-5400 cm^2/volt-sec and carriers of 1×10^{16} to 5×10^{17} per cm^3.

Dr. Staniforth also states that it is probable that the float zone refining method will make possible a high purity product which will open up new device areas for gallium arsenide, particularly the development of gallium arsenide transistors. Because of gallium arsenide's larger band gap and higher mobility over that of silicon

(*Continued on page* 66)

Market News . . .

...es

...panese exports of electronic products to the United States ...ing 1960 totaled $94.0 million, a 24% increase over 1959 accord... to the Electronics Division, BDSA of the U. S. Department of ...mmerce. The dollar value of transistors as shown, increased ...y 11.2%.

... Product	Quantity in thousands of units				Value in thousands of dollars			
	1957	1958	1959	1960	1957	1958	1959	1960
...dio receivers								
...ube type	n.s.s.	n.s.s.	457	881	n.s.s.	n.s.s.	2,552	6,277
...With 3 or more ... transistors	n.s.s.	n.s.s.	3,990	4,149	n.s.s.	n.s.s.	57,272	55,056
...nsistors	1	11	2,393	3,415	1	7	1,581	1,758
...iconductor ...evices, other	(1)	(1)	597	776	(1)	(1)	92	88

... Not reported separately prior to 1959; value included in "Other ...lectronic products."
...s. Not shown separately.
...urce: Data obtained by the U. S. Embassy, Tokyo, from the Japa...ese Ministry of Finance.

...he Department also has estimated domestic exports of crystal ...des and tranistors for 1960 at $15.97 million a rise of almost ...% over the $9.15 figure of 1959.

...ices

...Philco Corp.'s Lansdale Division has introduced a 2N779A ...ADT transistor for high speed switching circuits. Packaged in ...TO-18 case, prices are $8.03 each in quantities up to 99 units, ...89 on orders from 100-999, and $5.35 in lots above 1,000 units. ...ie firm has also established a price line for their entry into the ...nsistor test field. Their Virtue 201 is priced at $80,000 and their ...pid Index unit $75,000.

...Rheem Semiconductor Corp., Mountain View, California has ...nounced the creation of an industrial line of five types of ...ffused mesa silicon transistors, covering the full range from ...dio amplifiers to high-speed switching. Prices in 1,000 units ...nge from $1.60 to $3.85 each. The firm has increased the price ...otection of this industrial line up to 50,000 pieces. The firm has ...so developed a Si mesa transistor RT5202 designed to replace ...gh voltage relays. Available in TO-5 to TO-15 packages, the ...vice is priced at $33 each in 100-999 quantities.

...Sylvania has reduced the price of its 2N782 epitaxial germa...um mesa transistor. The new prices are $10.40 each in lots up ...99 units and $6.95 in quantities from 100-999. Their 2N783 with ...reported total switching time of 46 manoseconds is priced at ...2.50 each in quantities up to 99, and at $15 from 100-999 units. A ...milar unit 2N784 is listed at the same prices.

...General Electric Co., has reduced prices on three of their sili...on unijunction transistor by 41¢. The new prices range from ...80 to $2.15 each in quantities on types 2N1671, 2N1671A & ...N1671B.

...PRL Electronics, Inc., Rahway, N.J. has made available a line ...*dc-to-dc* transistorized static converters rated for 100w opera...on. Prices range from $70 to $81.25 each depending upon input ...nd output voltage requirements.

...Saratoga Semiconductor Division of Espey Manufacturing and ...lectronics Corp., Saratoga Springs, N.Y. has introduced a 1 watt ...licon Zener regulator in a ceramic case. Prices range from $3 ... $7. Glass encased versions are priced at $2 to $4.

...Raytheon Co.'s Semiconductor Division has announced the ...vailability of three *p-n-p* diffused-base high-speed germanium ...esa transistors. Types 2N705, 2N710 and 2N711 are enclosed in the ...O-18 case. In quantities of 100-999 these are priced at $10 for ...e 2N705, $5.10 for the 2N710 and $1.95 for the 2N711. The firm ...so has available a line of five stud-mounted Si power tran...stors. These double-ended devices are designated 2N1894 to ...N1898 are priced from $36 to $90 each in quantities up to 99, and ...om $24 to $60 in quantities from 100-999.

...Standard Rectifier Corp., Santa Ana, Cal. has entered the Zener ...eld by offering a line of 250 watt Zener diodes. The 250 ZE ...eries are available in a stud-mounted package and the 250 ZF ... a flange-mounted package. Prices range from $60 to $70 each.

Suppliers

Cetron Electronic Corporation, through its plastics division in Pasadena (Calif.), plans to market a new epoxy resin in the form of a pencil for industrial and household use. This non-toxic material is utilized by semiconductor manufacturers to seal transistors.

Financial

Eagle-Picher Co., has reported a decline of 21% in sales and a drop of more than 50% in earnings for the three-month period ending Feb. 28, 1961. Net sales were $25,002,735 compared with $31,667,459 in the 1960 first quarter. Earnings totaled $455,797 against $1,075,252 for the corresponding period last year.

Sales of Sprague Electric Company of North Adams, Massachusetts in 1960 increased to $64,523,956 from $56,351,571 in 1959. Net profit came to $4,882,042, including $795,279 of non-recurring profit from sale of patents and proprietary information rights to a British affiliate, Telegraph Condenser Company, Ltd. Net per share amounted to $3.40, including $0.55 for the non-recurring item, and was figured on 1,433,449 shares outstanding at year end. This compares with $2.61 in 1959. Dividends paid totalled $1.20 in cash plus 2% in stock, the same as the previous year.

Alloys Unlimited, Inc., of Long Island City, N.Y. and Cambridge, Massachusetts, announced the acquisition of Veritron West of North Hollywood, California, manufacturers of glass-to-metal seals used in semiconductor devices, relays, transducers and other electronic components.

Johnson & Hoffman Manufacturing Corporation, Mineola, Long Island, N.Y., a manufacturer of precision stampings and deep drawn parts, has purchased the inventory, machinery and equipment of the Stamping Division of The Fred Goat Co., Inc., Brooklyn, N.Y.

The New York Air Brake Company, New York, N.Y., recently announced that it had acquired Feedback Controls, Inc., Natick, Massachusetts, designers and manufacturers of servo components and systems, and electronic computation equipment.

Loral Electronics Corporation has announced that it is negotiating for the acquisition of Accurate Specialties Company, Inc., Hackensack, N.J., a developer and producer of high purity metals and ceramics for the electronics industry.

New Firms

Semtech Corp., has been formed in Newbury Park, Calif., to develop, manufacture and sell semiconductor power handling devices including power rectifiers. The firm is located in a 20,000-square-foot building.

Diotran Pacific, Palo Alto, California, has recently been established. The firm will concentrate on the design, development and manufacture of a broad cross-section of production and test equipment for semiconductor manufacturing.

Expansions

Alpha Metals Inc., Jersey City, N.J. has broken ground for a 10,000 square foot facility to adjoin its main plant. The addition will be used to bolster production of semiconductor alloys.

Semi-Alloys Inc., Mount Vernon, N.Y. has moved into its new 10,000 square foot plant. This will enable the firm to expand its stamping processes as well as house equipment for a planned development project on thermoelectric materials.

Eagle Picher Co., is moving its electronic metals and compounds plant to a 20,000 square foot facility near Miami, Okla.

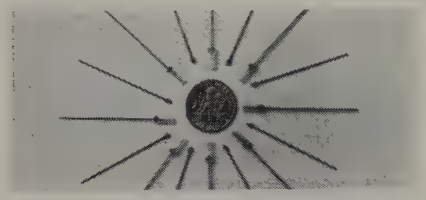
Merck and Co., Inc. has started construction of a full-scale plant in Danville, Pa. for production of epitaxial silicon wafers and a pilot plant for epitaxial germanium wafers. This will bring their total plant investment in semiconductor materials to $7 million.

National Semiconductor Corp., Danbury, Conn. has leased an additional 13,000 square feet to be used for executive offices and for research and development on its line of precision transistors.

(Continued on page 68)

New Products

Beaded Leads & Glass Seals



Beaded leads and glass seal sub-assemblies used in the manufacture of glass diodes are available from Electronic Glass and Ceramic Corporation, a division of Alloys Unlimited, Inc. Both moly and dumet studs with hard glass packages can be supplied. The sub-assemblies are being produced to fit individual diode manufacturers specifications on the latest automatic equipment.

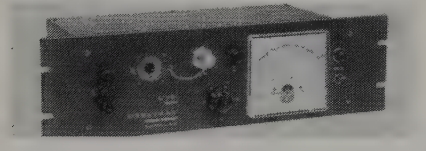
Circle 104 on Reader Service Card

Power Supply

An associated instrument, Type 125 powers from one to four Tektronix Type 122 Preamplifiers. It provides three different regulated supplies to these preamplifiers thru octal interconnecting cables. Output voltages include: +135 volts dc at 0-to-20 milliamperes ±3%, −90 volts dc at 0-to-20 milliamperes ±3%, −6 volts dc at 0.7-to-4 amperes ±5%. Dimensions are 10¾" high x 4¼" wide x 13¼" deep. Weight is 14½ pounds.

Circle 102 on Reader Service Card

Semiconductor Capacitance Test Set



Dynatran Model 1827 C_{ob} Test Set provides direct meter readings of the collector capacitance of transistors with ranges of 0-3, 0-10, 0-30 and 0-100 uufd full scale. The instrument has an accuracy of 5% and can also be used to measure the capacitance of diodes when reversed biased.

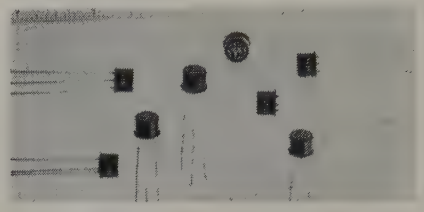
Circle 148 on Reader Service Card

Ultrasonic Cleaning Solutions

L & R Manufacturing Company announces the development of three specialized cleaning solutions for a wide range of ultrasonic applications. #222 is a waterless, ammonia-free solution that was especially formulated for cleaning operations where the use of ammonia would not be chemically desirable. #112, (ammoniated), is ideal for the removal of a wide variety of foreign particles from precision metal parts, instrument components and assemblies, transistors, etc. Hydro-Sonic Cleaning Solution Concentrate, when diluted with seven pints of water, will produce a gallon of water base ultrasonic cleaning solution capable of instantly removing all water-soluble soils, fingerprints, lapping compounds and cutting oils, etc., from metal, glass and plastic.

Circle 113 on Reader Service Card

Silicon Transistors



General Electric Company has announced eight new silicon mesa transistors, JEDEC types 2N497, 2N497A, 2N498, 2N498A, 2N656, 2N656A, 2N657 and 2N657A. Although designed for medium power applications (4 and 5 watts average continuous dissipation, maximum, with a case temperature of 25°C), the "A" versions will dissipate 20-watts peak power at 25°C with a pulse width of 0.8 milliseconds. They have a low maximum saturation resistance of 10-ohms as compared to the non "A" versions' maximum of 25-ohms. Base input resistance is 200-ohms, maximum, versus the non "A" versions' 500-ohms maximum.

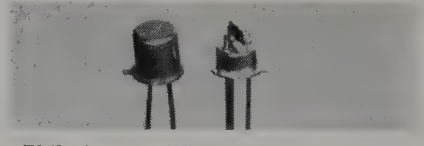
Circle 114 on Reader Service Card

Bottle For Reagent Acids

The J. T. Baker Chemical Co. has developed a new "Shure-Grip" 5-pint bottle for reagent acids, incorporating a finger-fitted jug-type handle to provide a safe, sure grip when lifting, pouring or carrying. The index finger grips the contoured handle opening with firm no-slip control while the thumb and third finger lock naturally into a safe comfortable position. The bottle also features the dripless pouring sleeve which helps achieve maximum safety when pouring.

Circle 103 on Reader Service Card

High Speed Switching Transistor



Philco's new 2N779A *MADT* transistor features ultra-high speed with very low saturation voltage. Saturation voltage is specified to be between .055 v and .125 v at −10 ma collector current. It switches 10 ma of current in a circuit having a gain of 10 in a total switching time of 52 nanoseconds. Saturation voltage spread and base voltage spread are both controlled to less than .07 volts. The device's capabilities are significant for computer applications.

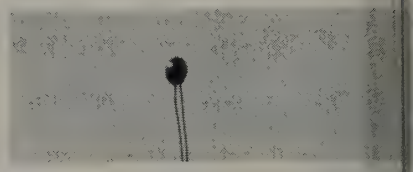
Circle 100 on Reader Service Card

Silicon Zener Diodes

Standard Rectifier Corp., has announced pilot production of 250 watt silicon Zener diodes which will be available in the 6 to 30 volt range with typical dynamic impedance of the higher voltage units being .06 ohms and lower voltage units to be considerably less. They are available in stud and flange mounted packages. Applications include systems surge protection, power supply regulations, and laboratory work.

Circle 128 on Reader Service Card

Silicon Oxide Capacitors



A new type of electric condenser usi semiconductor principles was recently i troduced by Sprague Electric Co. T device uses silicon oxide as the dielec material. It is expected to find wide a plication in digital computers and ot electronic equipment requiring extre stability of capacitance. The new cap tors will be marketed under the na OXSIL. Other features include a w operating temperature range up 300°F, high insulation resistance, low d sipation factor, and extremely low se inductance. Units are being furnished both radial and axial lead wafer desig Type 10K and 11K.

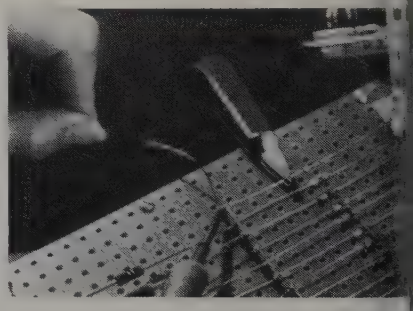
Circle 110 on Reader Service Card

Vacuum Pencils

Kulicke and Soffa Vacuum Pencils ha been developed for simple efficient ha dling of miniature dice and full-si wafers in semiconductor and transist manufacturing. Two different types a available: Model 650-V, knee and/ hand actuated valve type designed pick up minuscule particles (dice) utili ing any one of four interchangeable tip Model 652-V finger-aperture actuat valve type designed with two inte changeable tips, has suction cup tip f larger articles (wafers).

Circle 106 on Reader Service Card

Heat Sink



Latest addition to Hunter Tools' line electronic assembly tools is the #5 Heat Sink which clips onto any sma wire and dissipates heat while solderi Illustration shows a Hunter Heat Si protecting a delicate diode semiconduct while soldering operation is being pe formed. Model illustrated is larger three available models with an overa length of 2½". Smallest model is only in length.

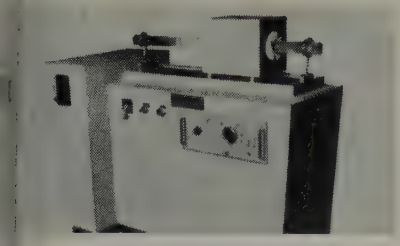
Circle 108 on Reader Service Card

Soldering Washer

A demonstration of how to solder transistor can and header together so to get maximum surface-to-surface co tact and complete peripheral fluxing these closely-fitting parts was recent shown by Alpha Metals, Inc. Involvi an Alpha flux-filled washer consisting a layer of flux sandwiched between tw layers of solder, the process is especiall effective when used with induction hea ing devices. Flux-filled washers relea the flux for instant action around the en tire periphery of the solder part, makin the soldering operation positive and e fective.

Circle 117 on Reader Service Card

rizontal Zone Refiner



new horizontal zone leveler has been ounced by Lindberg Engineering npany. Type RHR2-1Z23 is a com- ely packaged unit specifically de- ed for applications such as zone lev- g of germanium bars up to 18" long. ditionally, this particular type of fur- e design lends itself to epitaxial wth along with straight diffusion cesses. The furnace has a maximum rating temperature of 1093°C. The mber is 3" long and is heated by two g type nichrome heating elements ich provide a uniform heated length 1" at plus or minus 2.0°C.

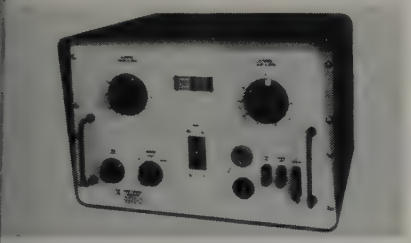
Circle 120 on Reader Service Card

ra-Fast Switching Transistor

Development of an ultra-fast silicon itching transistor has been announced Sylvania. The switching capabilities the new device have been achieved combining the advantages of mesa nstruction with epitaxial manufactur- g techniques. Designated Type 2N783, e small signal device has a maximum rn-on time of 16 nsec. and turn-off time 30 nsec. for a total switching time of ly 46 nsec. in a 2N706A test circuit with andard conditions.

Circle 111 on Reader Service Card

rge Test Instrument



A new surge test instrument that per- its surge testing of silicon rectifiers in ccordance with JAN specifications, is nnounced by Wallson Associates, Inc. The self-contained, portable unit, Model 20, permits surge testing with currents ontinually adjustable from 25 to 630 am- eres peak. It features single half-wave inusoidal pulse output; sync and cali- rated output monitor for oscilloscope isplay; and provision for sequential esting. Monitoring sensitivity is 1 MV er ampere; monitoring accuracy is ithin 1%. Sync output is 10 volts posi- ive; power input is 208-230 volts *a-c*, 0 cps.

Circle 109 on Reader Servic Card

ilicone Rubber

A free-flowing fluid silicone rubber that ulcanizes in sections of unlimited thick- ess at room temperature has been an- ounced by Dow Corning Corporation. Silastic RTV 601 rubber requires only the ddition of a catalyst and 24 hours time o set up into a rubbery solid. Cures ithout heat, pressure or moisture, even nder totally confined air-tight condi- ions. Variations in thickness have no ignificant effect on curing rate and uni- ormity, according to the company.

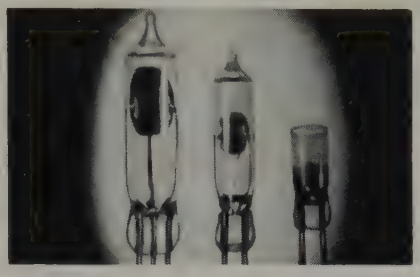
Circle 116 on Reader Service Card

Planar Epitaxial Transistor

Fairchild Semiconductor Corporation has introduced a planar epitaxial transistor, the 2N914. This new device makes use of both planar and epitaxial techniques, and is basically a high performance logic transistor with driver capabilities. It has a collector saturation voltage of 0.18 volts maximum at 10 ma collector and 1 ma base current. At 200 ma collector, 20 ma base current the transistor has a maximum saturation voltage of 0.7 volts.

Circle 129 on Reader Service Card

Lead Sulfide Photocells



New developments in the semiconductor field have enabled Cetron Electronic Corp., to offer a complete line of Lead Sulfide infrared cells. These subminiature all glass hermetically sealed cells are environmentally stable, with pins for socket mount or flexible leads. They are now being used, or are adaptable for use, in such equipment as electronic computers, temperature measuring devices, infrared communications apparatus and solar temperature computers.

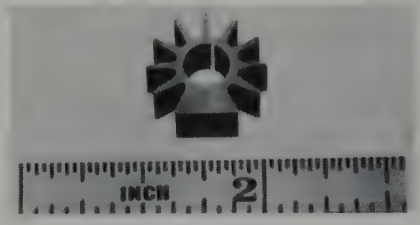
Circle 101 on Reader Service Card

Silicon "Stabistors"

Nine types of silicon "Stabistors" are now available from the Semiconductor Division of Hoffman Electronics Corporation. In power dissipation, they range from 200 milliwatts to 10 watts. They are particularly suited for meter protection, temperature sensing, base clamping, stabilized transistor bias, signal limiting, and transistor emitter varistor applications. JEDEC types 1N912, 1N912A, 1N913, and 1N913A and Hoffman Types HS-1 and HS-2 are encased in the rugged 500 milliwatt "glass" package. Type HS-3, a Silicon Junction Diode, is encased in the MI Case, Type HS-4 (1 watt) is encased in the MIA case, and type HS-5 (10 watt) is packaged in the SIE case.

Circle 115 on Reader Service Card

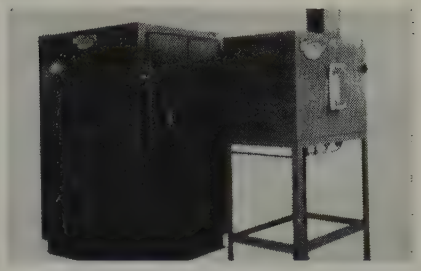
Heat Radiator



A new Birtcher heat radiator No. 3AL-724 for transistors with TO-18 packages is designed to increase transistor efficiency 25 to 27% and prevent thermal runaway. Material is aluminum per QQ-A-268 and anodize per MIL-A-8625. The 8-finned radiator's base can be tapped for either vertical or horizontal mounting on printed circuit boards or metal chassis. The radiator is slotted through the mounting hole to allow for case diameter variations.

Circle 107 on Reader Service Card

Induction Heating Generator



A generator has been introduced by Induction Heating Corporation which offers a common work-coil and two frequencies to provide research personnel with a convenient way of investigating the effects of frequency on zone refining. In this new design the common single turn work-coil can instantly be switched from 300 kc to 7 mc. A saturable reactor is utilized for output control, with provision for manual or automatic operation. The generator will serve in practically any induction heating process.

Circle 118 on Reader Service Card

Thermistor

A new positive-temperature-coefficient thermistor has been announced by The Carborundum Company. This thermistor fills the need for temperature compensation, sensing and control in many applications that include transistorized circuitry, crystal ovens, etc. A life test recently in progress @ 150°C showed no change in resistance after 500 hours.

Circle 141 on Reader Service Card

Temperature Controlled Ovens

Monitor Products Company recently announced a complete line of 87 different design temperature controlled ovens to hold crystals, diodes, transistors, and many other electronic components. The company states these ovens have stabilities to ±.003°C, high reliability, and meet MIL specs. The company further states that in addition to their 87 standard ovens, many special ovens are available with or without modifications to fill the needs of any temperature control problems encountered by the design engineer.

Circle 131 on Reader Service Card

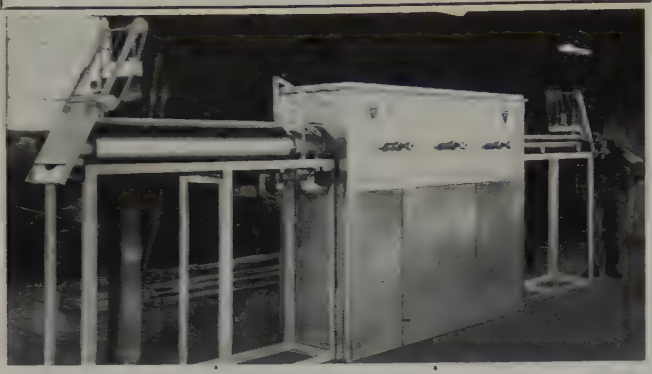
Semi-Automatic Test Equipment

A new system for high speed testing of electronic components has been introduced by General Precision's Librascope Division. Called SATE, for Semi-Automatic Test Equipment, it will evaluate components for combinations of ten parameters and accept or reject each at a machine rate of 1800 components per hour. Each module in the electronic console controls one of ten test stations in the mechanical handling console and is provided with controls for setting test conditions and establishing parameter limits.

Circle 122 on Reader Service Card

(Continued on page 69)

Carbon Resistor
PERECO Tube FURNACES



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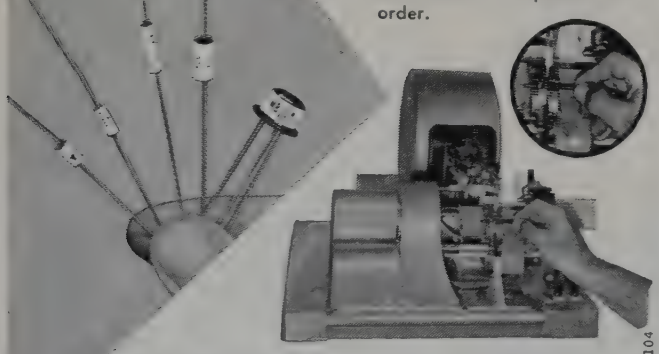

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Circle No. 30 on Reader Service Card

Industry News (R&D)

(*from page 62*)

and germanium, such transistors could be expected to operate at substantially higher frequencies and temperatures. Using a modified process, the company produces 600 to 800 gram polycrystalline gallium arsenide ingots in lengths up to 15 inches, with grain sizes in the centimeter range. For tunnel diodes and microwave diodes, polycrystalline gallium arsenides doped with zinc, cadmium, manganese, germanium, platinum, tin, sulphur, selenium, tellurium, antimony and lead are offered. These doped products have carrier concentrations ranging from 10^{17} to greater than 10^{20} per cm^3.

A new electrochemical technique for rapid, scratch-free polishing of germanium and silicon wafers for transistors was recently revealed by M. V. Sullivan of Bell Telephone Laboratories, Murray Hill, New Jersey. One of the major problems in the manufacture of transistors is maintaining an undamaged surface on the semiconductor slice used for the active element of the device. When there are deep scratches from lapping and polishing, the etchant cannot remove all the damage, and poor-quality transistors result. In contrast, electrochemical polishing does not introduce new damage during processing.

In the technique Mr. Sullivan described, semiconductor slices are mounted on a nonconducting disk. After electrical contact is made to the slices, they are placed on a polishing wheel over which an electrolyte flows. When the polishing wheel rotates, a film of electrolyte, whose thickness is determined principally by the viscosity of the electrolyte, separates and automatically maintains the semiconductor at a relatively constant distance from the wheel. Dilute potassium hydroxide is the electrolyte used for the electropolishing of germanium and dilute hydrofluoric acid is used for silicon. For *n*-type material, either germanium or silicon, it is desirable to illuminate the semiconductor surface during electroetching.

The smoothness of the surface obtained by this method is apparent through study of photomicrographs of comparative surfaces. A mechanically polished surface shows distinct scratches when magnified 500 times. These scratches are caused by broken pieces of abrasive and semiconductor, which are ground into the face of the polished slice. On the other hand, semiconductor slices polished by this new technique show no texture that can be associated with surface roughness even under electron-microscope examination at 53,000 power.

A new, efficient device for converting electrical energy into ultrasonic energy and vice versa at microwave frequencies was described by D. L. White of Bell Telephone Laboratories. The device is a piezoelectric transducer utilizing a semiconductor depletion layer. It is expected to be employed primarily in ultrasonic delay lines where its operation at high frequencies and wide bandwidths will make it possible to store large amounts of information. Another possible use will be as a tool for studying the acoustical properties of materials at higher ultrasonic frequencies. It is anticipated that large amplitude ultrasonic waves can be generated in materials at microwave frequencies and also extremely weak waves can be detected with greater efficiency than with existing transducers.

(*continued on page 69*)

1 2 3 4 5 6 7 8 9 count to 10

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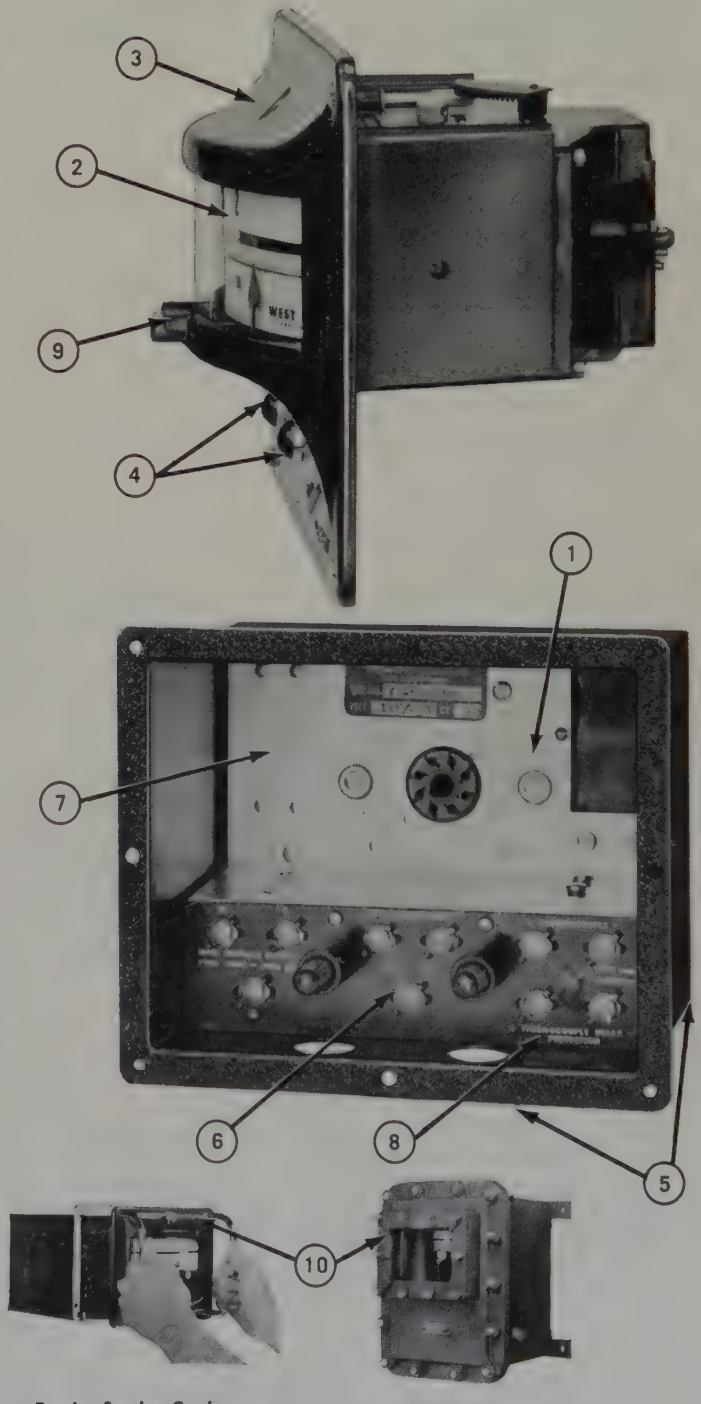

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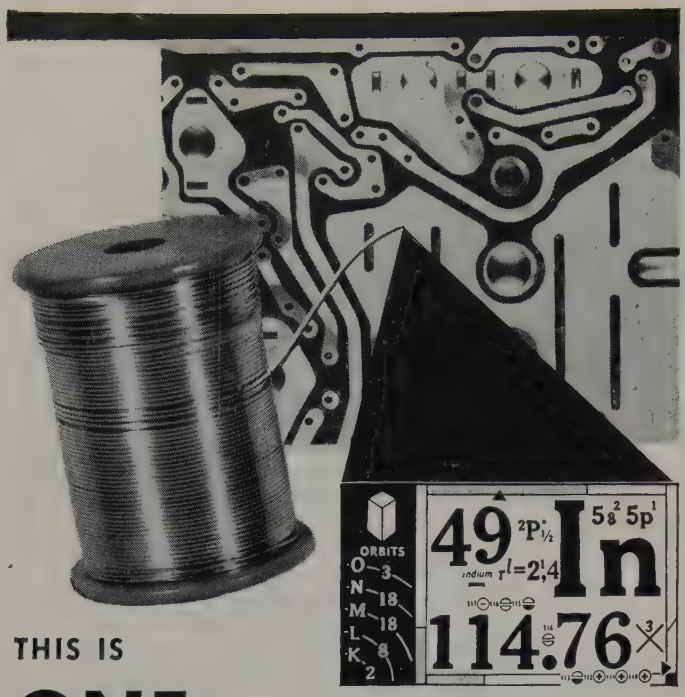

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Circle No. 32 on Reader Service Card

Market News

(from page 63)

Allen-Jones, Inc., Long Beach, California, has announced the formation of a new Semiconductor Materials Processing Division to provide the electronic and semiconductor industry with service for slicing, lapping, dicing and the ultrasonic cutting of custom shapes from silicon, germanium, ceramics and 3-5 compounds.

TI expanded all phases of its international operations during 1960. Overseas plant capacity was increased by nearly 200,000 sq ft, including completion of a new 132,000 sq ft plant at Bedford, England for the manufacture of semiconductor devices for marketing primarily in the United Kingdom. A new subsidiary company was established in France to manufacture semiconductors for marketing within the European Common Market.

ERRATUM

In our February 1961 Market News section on page 55 of that issue, under the heading of "Expansions," we published an item about the reorganization of Tang Industries, Inc., Natick, Mass. The wording of this story gave the erroneous impression that Tang is engaged in semiconductor device manufacture. The corporation does not presently nor intend to in the future manufacture diodes, transistors or rectifiers, and is in fact entirely devoted to serving the semiconductor device manufacturer. In an effort to correct the previous misinterpretation, and to clarify this company's facilities for our readers, we are publishing a description of their operation.

Tang Industries, Inc. of Massachusetts (recently renamed Tang Semiconductor Materials, Inc.) and Integron, Inc. of Waltham, Mass. are subsidiaries of Tang Industries, Inc. of Delaware.
Tang Semiconductor Materials, Inc. has been supplying silicon and germanium material in ingot and fabricated form to the Semiconductor, Infrared and Strain Gauge industry for over two years. This is strictly a materials company working to customers' specifications, specializing in controlled dislocations and resistivities. It is constantly involved in development work, but not on diodes, rectifiers and transistors. The development work is confined to improving methods of growing, slicing, lapping and polishing the materials, so that they can continue to supply a product of quality to the Semiconductor Industry.
Integron, Inc. was acquired by Tang Industries, Inc. of Delaware in August, 1960. Integron, Inc. is made up of four divisions, which are as follows:

Engineering Service Division:
This division has been supplying technical assistance to Electronic Industry and prime government contractors for over ten years. They are staffed with electronic, electrical and mechanical engineers, designers, draftsman and checkers who are capable of taking a project from the design stage to manufacturing in their own plant, or loaned out to companies to supplement their engineering departments.

Equipment & Manufacturing Division:
This division designs and builds automatic controlled production equipment, primarily for the Semiconductor Industry.

Systems & Instrumentation Division:
This division is divided into two departments. One department has been in the design, development and manufacture of Anti-Submarine Warfare and Underwater Systems and instrumentation for approximately ten years, working to custom specifications for the major government agencies.
The other department is engaged in intensive research and development on semiconductor strain gauges and other energy conversion products. Some of these projects, such as the strain gauges are now being produced to customer specification.

Semiconductor Application and Processing Division:
This division is a research and development group, developing techniques in using new materials for the semiconductor industry, for example, intermetallic materials such as indium antimonide and gallium arsenide. For the last six months this division has been vigorously engaged in research and development on silicon and germanium epitaxial wafers. They are now supplying these wafers to the industry on a production basis. In conjunction with the aforementioned projects they are actively engaged in developing micro-electronic circuitry by applying epitaxial techniques.

stry News (R&D)

n page 66)

e depletion layer transducer has several advantages n an ordinary transducer:

f) Because the layer is so thin, the greatest efficiency he transducer is at very high frequencies. Current els operate at under 1000 mc but the frequency range xpected to be extended to above 10,000 mc. In this n frequency range, this transducer should be as much one hundred times more efficient than any other wn transducer. With a highly efficient transducer, ll electric signals can generate ultrasonic waves and weak ultrasonic waves can be detected.

2) The thickness of the layer, hence the resonant fre- ncy of the transducer can be varied by varying the bias voltage. This adds great flexibility to its use. nventional piezoelectric transducers do not have this ture.)

3) Present models measured at 600 mc have a band- dth of 5% (30 mc), an order of magnitude larger than ical ceramic transducers, operating at frequencies be- 10 mc. This means that a comparable increase should expected in the amount of information which can be nsmitted. It is expected that, with operation at higher quencies, even wider bandwidths can be achieved.

4) The transducer is relatively simple to make and y to handle.

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w Products

om page 65)

nsistor Heat Dissipator

Accel Electronic Products' Uni-Mount a 7 to 10 watt power transistor heat sipator. It is a small-sized improved ans of mounting large round and dia- nd shape (TO3, TO6) power transistors th both transistor and electrode con- ctions on the same side of the mount- wall. It removes transistors from out- e equipment cabinet to inside out of ht, eliminating accidental short cir- iting, impact damage and potential zards.

Circle 139 on Reader Service Card

lly Passivated Micro-Matrices

MicroSemiconductor Corporation re- ntly announced the availability of sili- micro-matrices, fully-passivated, mmon, active substrate diode arrays, signed to customer-specified geometry, e, electrical and contact requirements. chniques are used in these structures produce a micro-size silicon matrix t will withstand long term storage at °C without degradation. This enables stems engineers and circuit designers to tend significantly the exploration of cro-electronics by developing their own cuits on active substrates.

Circle 142 on Reader Service Card

Automatic Switching Time Tester

Automated testing of nanosecond switching devices and circuits is possible with the Model 400 Series Automatic Switching Time Test Set manufactured by Lumatron Electronics, Inc. Rapid, accurate measurements from 0.5ns to several microseconds can be made at rates up to 3600 tests per hour. Risetime, falltime, storage and delay characteristics are read directly on a meter with an accuracy of better than 5%. In addition, the test results can be converted to digital information, permitting automated readout. The instrument is particularly adapted to measure transistor switching parameters. However, the switching times of other devices such as tunnel diodes and computer circuits can also be measured automatically.

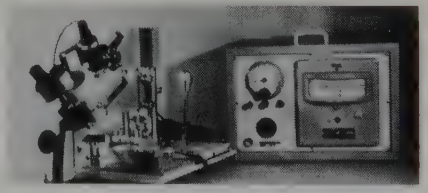
Circle 119 on Reader Service Card

Silicon Controlled Rectifiers

Tyco Semiconductor Corporation has announced the availability of silicon controlled rectifiers with average forward current handling capacities up to 16 amperes at 65°C. Types 2N681 through 2N689 comprise the 16 ampere series and types 2N1842 through 2N1850 complete a 10 ampere product line. Both series feature peak reverse voltage ratings to 500 volts, low forward voltage drops (2.2 volts maximum at 16 amperes measured at —65°C for the 2N681 through 2N689) and uniform gating characteristics.

Circle 127 on Reader Service Card

Bonding Machine



Electroglas Inc., announces Model SP-2 thermal-compression nailhead bonding machine. This unit is complete with microscope, illuminator and temperature control unit. A single micromanipulator controls both gold wire positioning and bonding cycle. The machine is fully automatic with precise time and temperature control. An automatic cutting torch insures gold ball uniformity. Wire sizes down to .0005" diameter have been bonded to silicon and metallized surfaces of mesa transistors and micrologic elements.

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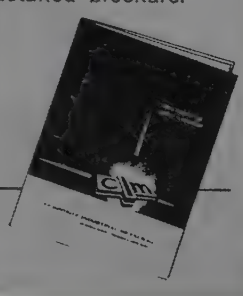
CIM is prepared to produce flat, burr-free parts in clad or solid metals for your semiconductor needs. Write for our informative and detailed brochure.



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Circle No. 35 on Reader Service Card

Photocell

A new type of Photocell, the Photr has been introduced by Solid State Pro ucts, Inc. It offers useful properties many types of electro-optical control s tems and is a highly efficient light-ac ated *p-n-p-n* Silicon Switch, having very high impedance (over 10 megohm when "off" and a very low impeda (under 10 ohms) when triggered "on" light. Its output is determined prima by the load and is independent of lig input at all intensities above the trigg ing level. Although miniature in s (.185 dia. x .200 long), it can deliver to 300 mA load current at up to 200 vo with an efficiency exceeding 98%.

Circle 140 on Reader Service Card

Diode Tester

Trans Electronics, Inc. has introduc an advanced model of its highly sensiti diode tester, with expanded capabiliti in the semiconductor low current a high voltage ranges. The DT 924 is back-current and saturation volta tester with meter ranges of 0 to 3 volts, 0 to 3000 microamps, and 0 to 3 milli-microamps. This unit provides re ulation of better than 0.1%; ripple a noise, 0.05%. Output current is 0-1 m output voltage, 0-3000 volts.

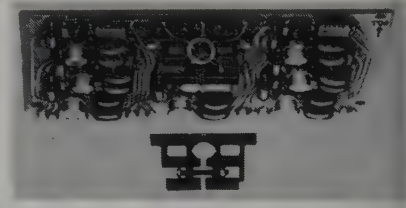
Circle 121 on Reader Service Card

Silicon Transistor

2N697A, a new ultra-versatile silic transistor has been announced by Rhee Semiconductor Corporation. It is said combine very fast switching with exce lent amplifier characteristics, making possible to specify one type for bo applications. For amplifier applications has excellent beta levels guaranteed eight points. Other features include watt power dissipation and guarante small signal parameters. RT697A(M), a nounced at the same time, provides t same combination of electrical characte istics in the high efficiency Microbl package.

Circle 130 on Reader Service Card

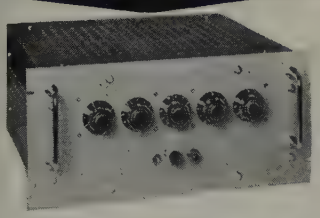
Heat Sinks



A new series of small, light natura convection transistor heat sinks whic provide maximum heat dissipation a being manufactured by Astro Dynamic Inc. Developed to satisfy the needs of th electronic engineer concerned with th reduction of space and weight in the de sign of component boards for computer Model 2700 series substantially increas transistor performance by optimizing th effect of the heat transfer coefficien available in free convection. Thermal Re sistance: #2701—28°C/Watt; #2702—23°C Watt; #2703—18°C/Watt.

Circle 135 on Reader Service Card

NORTH HILLS'



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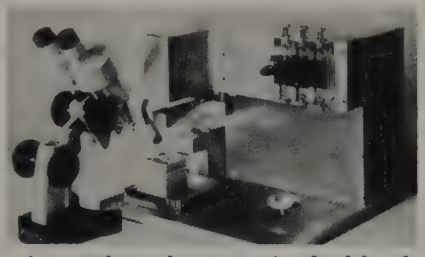
SEMICONDUCTOR PRODUCTS is making a new source of information available to all firms interested in being kept up to date on materials or equipment for producing semiconductor devices. If you wish to receive all new literature on silicon, germanium, chemicals, machinery, or other such materials, circle #99 on the reader-service card. Your name will be placed on a special list which will be forwarded to all such suppliers. As these suppliers have news available in their field, you'll be notified by them immediately. This service is restricted to firms manufacturing semiconductor devices or firms contemplating entering into production within 120 days.

Transistor Heat Sinks

A simple aid to increased reliability and efficiency of transistorized military and industrial devices is offered by transistor dielectric heat sinks now available from National Beryllia Corporation. Used to insulate semiconductor devices from the chassis, these heat sinks utilize beryllium oxide's ability to resist the flow of electricity but not the flow of heat, allowing higher power without exceeding temperature limits. In addition to electrical resistivity exceeding 10^{15} ohm-cm and thermal conductivity equal to that of aluminum, Berlox heat sinks have extremely-low dielectric loss (less than .0008) over the entire frequency range at which semiconductors are applied.

Circle 126 on Reader Service Card

Lead Bonding Machine



A new thermal compression lead bonding machine for semiconductor manufacturing is announced by Diotran Pacific. The lead bonder provides fast, accurate bonding of gold wire to semiconductor materials. High precision micro-manipulation, excellent optical system, and high output heater assembly insure one-time, positive bonding, substantially reduces rejects. Gold wire and wire housing are fully protected by gas-filled envelope. Built-in, precision flame cutting tip severs and "balls" wire cleanly.

Circle 136 on Reader Service Card

Electronic Component Coating

A new, one-component coating especially suitable for use on capacitors, resistors, transistors, diodes, and many other electronic components is announced by Columbia Technical Corporation. This transparent coating, HumiSeal Type 1F19, dries at room temperature becoming tack-free within thirty minutes and is then oven-cured. It is suitable for operating temperatures up to 350°F and down to −90°F.

Circle 134 on Reader Service Card

Ultrasonic Drill

A new Glennite Ultrasonic Drill, Model D-101A, has been introduced by Gulton Industries, Inc. Product improvements make the new drill almost twice as efficient in multiple machining, slicing, cutting and etching operations as the older Model D-100A, which it supersedes. The new drill will handle tool sizes up to ¾" on a diagonal. Sample per minute rates using this size tool include glass at .200", ceramic .060", ruby .010", germanium .050", among others.

Circle 138 on Reader Service Card

Shaker Baths

Any laboratory test requiring precisely controlled temperature as well as controlled agitation can be made with 100% repeatability when using a new line of stainless steel Shaker Baths introduced by Precision Scientific Company. Bath temperature range is from ambient to 100°C with a guaranteed uniformity of ±0.5°C or better.

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Los Angeles, Calif.	Zenith	9-9964
Norwalk, Conn.	Enterprise	6046
Philadelphia, Pa.	Enterprise	6363
Rochester, N. Y.	Enterprise	6046
San Francisco, California	Enterprise	1-6146
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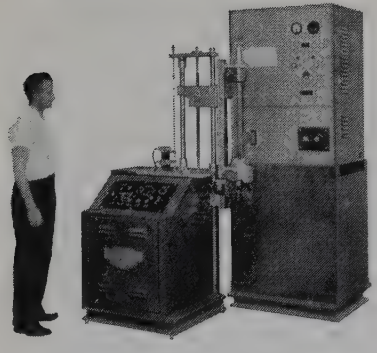
New! THER-MONIC Floating Zone Scanner

for refining and crystal growing!



Ther-Monic offers you precision equipment possessing an outstanding degree of flexibility of control in refining highest purity semi-conductors and various other metals.

Ther-Monic also manufactures production machinery for many other operations in the semi-conductor industry.

Ther-Monic R.F. generators — single and dual frequency — are available from 1 KW to 125 KW output.

Several thousand induction heating installations in numerous industries attest to the efficiency and economy of Ther-Monic equipment.

Write for New 56-page Catalog FZ

INDUCTION HEATING CORPORATION

181 WYTHE AVENUE, BROOKLYN 11, N.Y.

Largest Producers of Electronic Heat Treating Equipment

Subsidiary of Hathaway Instruments, Inc.

Circle No. 38 on Reader Service Card

Rectifier Cooler

Wakefield Engineering, Inc. new dua purpose semiconductor cooler, Delta Model NC-423 offers extremely low the mal resistance per unit volume; wit stock models affording .8°C/W with nat ral convection and as low as .3°C/W wit forced air. Optimum spacing of fins, plu high base conductivity, maximizes eff ciency. Specially engineered units fo high-power rectifier stack designs, wit natural convection thermal resistance a low as .5°C/W available, eliminating de rating of rectifiers and SCRs.

Circle 144 on Reader Service Card

Tiny Plating Machine

A compact plating unit measuring onl 30" x 26" x 18" to the work top contain all the equipment and features for pre cision-plating of jewelry, electroni parts, specification precious metal plat ing, or "pilot plant" set-ups, according t an announcement from The Meake Company, subsidiary of Sel-Rex Corpo ration. A completely re-designed smalle version of this firm's Jet Plater, the new models are said to permit either barre or rack plating with any cold alkalin solution, and most acid plating solution on a mass-production basis.

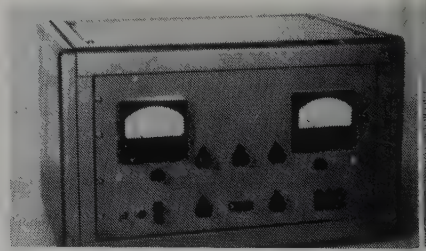
Circle 125 on Reader Service Card

Dustless Finger Covers

The Akwell Corporation announces th addition of a new Industrial Products Di vision to make finger cots for contami nation control for electronic and spac industries. Its laboratories developed special process which renders the finge cots "dustless," a characteristic essentia to the cleanliness standards for assem bling delicate components like semicon ductors and other sensitive parts. Finge cots are rubber covers which separately cover each finger. They are exceptionally thin-walled for finger dexterity and flexi bility in handling products.

Circle 133 on Reader Service Card

Parameter Tester



Tenco Electronics new h Parameter Tester will test the four h parameters of any signal transistor to an accuracy of 2%, over wide operating ranges, and in either grounded base or grounded emitter configurations. The equipment does not require *d-c* or *a-c* rebalancing when switching between grounded base and grounded emitter conditions, for all *d-c* circuitry is completely isolated from the testing circuits. As a result of this design feature, the speed with which transistors can be tested is significantly increased.

Circle 123 on Reader Service Card

Semiconductor Technology

orton Company's Machine Tool Divi- has purchased the rights to, and will in manufacturing, two new machines d in the wafering and lapping of semi- ductor materials. The Multi-Blade fering Machine is designed to cut ap- ximately 300 wafers .010" thick from ngle ingot in one operation. The Four- y Lapping Machine produces ultra- wafers lapped to extremely close erances of thickness and parallelism.

he wafering machine consists basically a series of very thin steel blades, pre- ly spaced and under tension, which the ingot with a reciprocating motion. slurry of silicon carbide or boron car- e acts as the cutting medium together h the thin steel blades.

t occupies a floor space only 2x4 feet l is driven by a ¼ H.P. motor operat- from any 110 volt, a-c power source. cause the operation is automatic, one erator can tend several machines. The des are .008" thick or less thereby cut- g a narrower kerf. The saving in mate- l is the most important single advan- e of the machine because of the high st of both germanium and silicon ingots.

The lapping machine is a table top ed machine, about two feet in diameter hich also operates from a ¼ H.P. motor m any 110 volt a-c power source. Its sign insures stress free lapping, an im- rtant feature in handling very thin and ittle materials. There are two models, e handling work as thin as .006" and e other designed for lapping to .003". afer breakage due to lapping is practi- lly eliminated. Irregular or broken aters can be lapped in the machine thout danger of their sliding under the rriers and scratching other wafers ing lapped.

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1.00 Each

1958—Jan/Feb; March/April; May/June; Nov/Dec.

1959—Sept, Nov, Dec.

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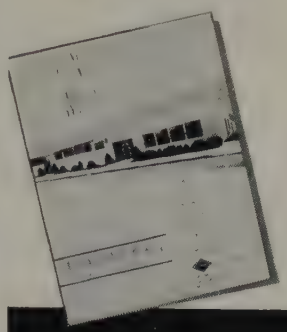
Custom Melting, Complete Redrawing, Strand and Vacuum Annealing Services for fine wire processing to customers' specifications.



WRITE for valuable brochure containing fine wire compositions, pertinent properties and applications.

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(Purity 99.99 and 99.9999%)

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Now Available From Consolidated Aluminum Corporation

Gallium is finding increasing use in compounds in the semi-conductor field. Ultra high purity aluminum (99.9999%) is in growing demand in a number of areas. Both are now available from CONALCO through its recently acquired subsidiary, AIAG Metals, Inc. AIAG Metals, Inc., is the exclusive United States distributor of ultra high purity aluminum and gallium produced by Aluminum Industrie, A. G., of Switzerland under the most rigid controls. For further information on new developments in gallium, please write:

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CONSOLIDATED ALUMINUM CORPORATION

General Sales Office, 9 Rockefeller Plaza, New York, N. Y.

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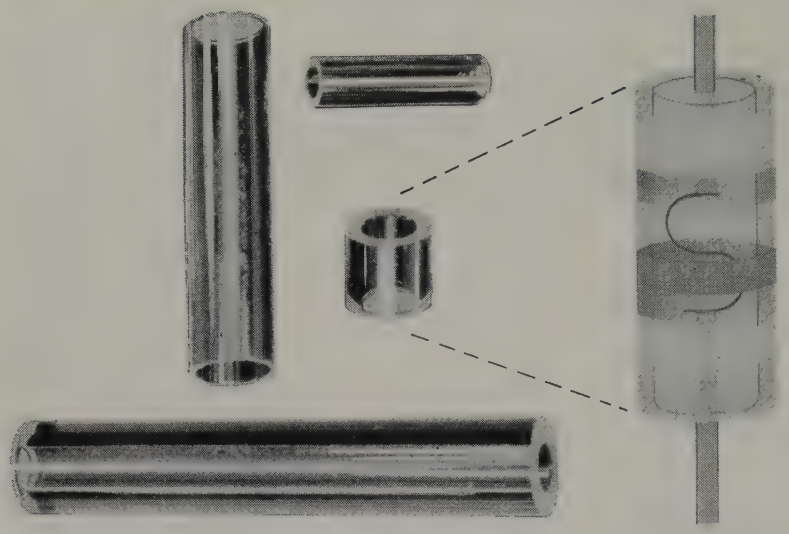

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Personnel Notes

Dr. Peter I. Pollak has been appointed director of the electronic chemicals research department of the Merck Sharp & Dohme Research Laboratories, a division of Merck & Co., Inc. Other researchers named to the new department include Dr. Walter C. Benzing, manager of process engineering and metallurgy; John J. Allegretti, semiconductor technology; Dr. John B. Conn, thermoelectrics; and Dr. William J. McAleer, semiconductor chemistry.

James C. Kershner has been named Purchasing Agent by Monitor Systems, Inc., Fort Washington, Pa., designers and manufacturers of advanced high-speed electronic data systems for defense and industry.

Edward C. Jones has been named sales engineering manager of VecTrol Engineering, Inc., it was announced by Gilbert B. Devey, general manager. VecTrol Engineering, Inc., a subsidiary of the Sprague Electric Company, manufactures packaged silicon-rectifier control circuits for use in industrial electrical equipment.

Wilbert E. Stevenson, president of The Machlett Laboratories, Inc., a division of Raytheon Company, was elected chairman of the board of Trans-Sil Corp. when that firm became a wholly-owned subsidiary of Raytheon early in April. Louis J. Grennell was also re-elected a president.

The appointment of Lester K. Suydam, Jr., as semiconductor sales engineer for Philco's Lansdale Division was announced recently. William F. Maher, manager semiconductor sales, stated that Mr. Suydam has been assigned to the division's Syracuse, New York Office.

The appointment of Actor H. Patton as director of product development for Allied Chemical's General Chemical Division is announced by Frank J. French, president.

Allied Radio Corp., Chicago, electronic parts distributor, announces the appointment of Ronald Kramer as product merchandiser of semiconductors, resistors, capacitors and special purpose industrial tubes.

A. H. Jacobson, Jr., has been elected Executive Vice-President and General Manager of Knapic Electro-Physics, Inc., Palo Alto, California. He was formerly Associate Dean of the College of Engineering and Architecture, Pennsylvania State University, State College, Pennsylvania.

A. Stanley Nelson, Jr. has been appointed general manager of the newly created division of Alloys Unlimited, Inc. The Electronic Glass and Ceramic Corporation, Cambridge, Massachusetts. He will be responsible for the operation of the entire division whose production will consist primarily of first seal and beaded lead sub-assemblies used in the manufacture of glass diodes by the semiconductor industry.

L & R ULTRASONIC CLEANING SOLUTIONS

L & R #112 Waterless Ultrasonic Instrument Cleaning Solution (Ammoniated)

L & R #222 Waterless Ultrasonic Instrument Cleaning Solution (Ammonia-free)

L & R Hydro-Sonic Cleaning Solution Concentrate

are *specific!*

We'll prove it! Send us small parts you find difficult to clean for test cleaning in our laboratory. We will do the job and return the cleaned parts to you, together with a recommendation for the right L & R cleaning solution which you can use in your ultrasonic cleaning equipment. For over 30 years L & R has been a world leader in precision cleaning for the watch and instrument fields. This experience is at your disposal. Or write for a copy of our latest catalog describing L & R's ultrasonic cleaning and rinsing solutions and ultrasonic cleaning equipment.

WATCHWORD OF THE WATCHMAKER

L & R MANUFACTURING COMPANY

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Circle No. 42 on Reader Service Card

KANTHAL LABORATORY FURNACES FOR HIGH HEAT

Electric laboratory furnaces, designed for Kanthal Super Cermet Elements and for REH Tubular Elements, provide continuously high temperatures at remarkably low cost.

Kanthal Super Elements provide continuous furnace operating temperatures up to 2700°F and 2900°F in Tubular and Box Furnaces. Furnaces are supplied with platinum-rhodium thermocouples.

Kanthal REH Tubular Elements provide continuous furnace temperatures of 2370°F, and intermittent temperatures up to 2460°F. Type RH-1 tubular furnaces are supplied with thermocouple and safety fuse.

Element	Furnace Type	Chamber Dimensions
Kanthal Super	Box	Up to 12" x 8" x 7"
Kanthal Super	Tubular	Up to 2-3/4" ID x 29" long
REH	Tubular only	IDs of 1-9/16", 2-3/4", or 4" in 7-7/8" or 19-3/4" lengths

Elements and parts available separately. Write for complete data and prices.

THE KANTHAL CORPORATION
19 Amelia Place, Stamford, Conn.
Canadian Rep., Ferro Enamels, Ont. Canada

Circle No. 44 on Reader Service Card

NEW RESEARCH AID

SEMICONDUCTOR ALLOY KIT NO. Z-100

In order to satisfy the needs of semiconductor research and development engineers for development quantities of high purity alloy preforms, Accurate Specialties Co., Inc. has now made available this unique semiconductor alloy kit. Using this kit, research engineers can now speed the development of new devices and processes, without the delays and setup costs previously encountered in procuring small development lots.

Note . . .

Kit Z-100 consists of 24 different semiconductor alloys in various useable forms such as discs, washers, and spheres. In excess of 25,000 preforms, in alloys with melting points from 325 to 1100 deg. F., are contained in this kit.

Accurate Specialties Co., Inc., metallurgical staff welcomes your inquiry regarding this kit, or your special semiconductor materials requirements.

price $100.00 F.O.B. plant

ACCURATE Specialties Co., Inc.

Ask for Bulletin Z-100 Dept. SP-5

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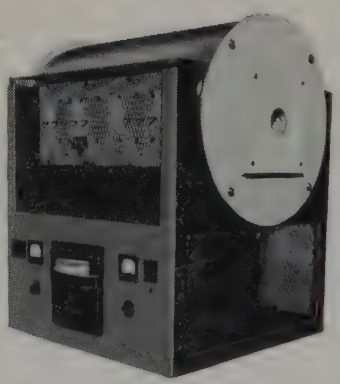
DESPATCH *tube* FURNACE WITH NEW *THERMIONIK* POWER SYSTEM



Model SC-32
Temperatures to 2600° F.
7 KW, 120/1/60 VAC
Ceramic Tube 2½" O.D.x36"

This versatile new tube furnace offers two outstanding advantages—the Thermionik power system, and a greatly reduced heat dissipation.

The Thermionik power system is the first and only to use thyratrons to pulse power to heaters. It allows great savings in cost, space and weight, and temperature control accuracy is limited only by the accuracy of the sensing control system selected.

Heat dissipation is kept to a minimum because body is made of castable refractory with highest insulating qualities.

Automatic or manual control. Muffle type and special models available.

For additional information, write today for free bulletin 206-5J4.

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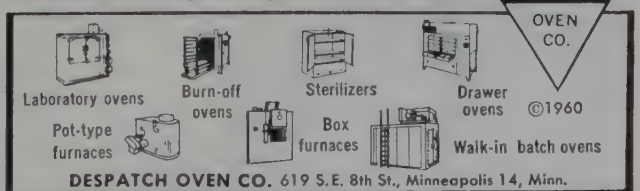

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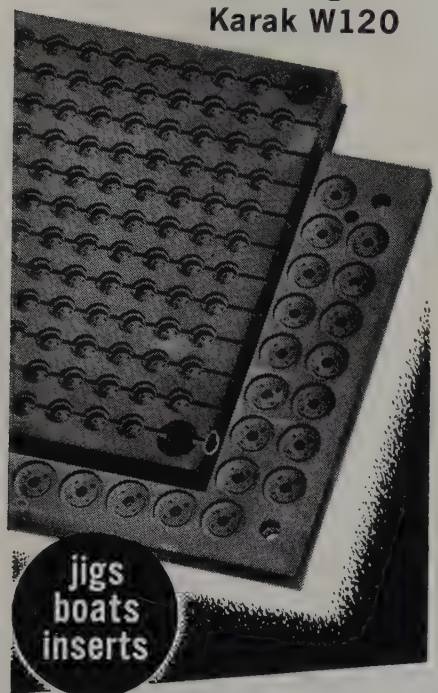
acceptance won...
growing preference...
reasons why...

Industry preference in glass-to-metal sealing is now growing for Karak W120



because:

Low ash content
No trace of rare earths
No trace of arsenics
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Average hardness of 68
(Shore Scleroscope)
Average apparent density of 1.68
Exceptional life reported
Extreme resistance to thermal shock
Dimensional stability
Cannot fuse to molten glass or metal

FREE ON REQUEST: a certified copy of the report of an independent Spectrographic Laboratory, on their analysis of the ash content of Karak W120.

THE OHIO CARBON COMPANY
12508 Berea Road,
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Circle No. 46 on Reader Service Card

New Literature

A new four-page illustrated bulletin describing General Electric's recently developed clear silicone potting compound (LTV-602), is now available from the company's Silicone Products Department. Designated CDS-280, the bulletin lists the complete properties of the new compound and outlines a simple procedure for preparing it for use. Publication is vividly illustrated with many photos.

Circle 161 on Reader Service Card

Two separate, 2-page sheets give a detailed presentation of various probes which preserve the transient response of Tektronix Instruments: for *dc*-to-30 mc oscilloscopes: series of twenty-four probe assemblies offers choice of three attenuation ratios and four cable lengths terminated in either a BNC or UHF connector; for *dc*-to-15 mc oscilloscopes: series of eight probe assemblies with attenuation ratio of 10 to 1 with choice of four cable lengths and either BNC or UHF connector.

Circle 162 on Reader Service Card

Electronic Research Associates, Inc., announces the availability of a new two color catalog sheet #121 which describes the company's new Tunnel Diode Power Source, Model TD6M. The catalog sheet provides full technical and descriptive data on this new design.

Circle 163 on Reader Service Card

The Lansdale Division of Philco Corporation has published a "Transistor Guide for Communications Circuit Designers." The guide presents a comprehensive summary of the basic ground rules to be followed in designing transistorized communications circuits. Valuable rules of thumb are included to provide circuit designers with a practical understanding of the results that can be expected from transistorized communications equipment.

Circle 164 on Reader Service Card

A new 16-page catalog (1-HR) describes Birtcher transistor/diode heat radiators available from stock. Details and drawings of more than 72 semiconductor radiators are listed for most TO case outlines. As an aid in ordering various radiators, TO case outlines are dimensioned and cross-referenced to all Birtcher part numbers. The catalog also includes a comprehensive handbook on thermal cooling.

Circle 165 on Reader Service Card

Bulletin Z-109, a 2-page data sheet describing high purity precision solder foil, is now available from Accurate Specialties Co. The bulletin includes complete specifications on solder foil, listing minimum thickness of .0005", widths to 6.00" maximum with tolerances on thickness held to plus or minus .0001". In addition to special alloys, the bulletin lists on page 2 data on 32 standard alloys available as foil.

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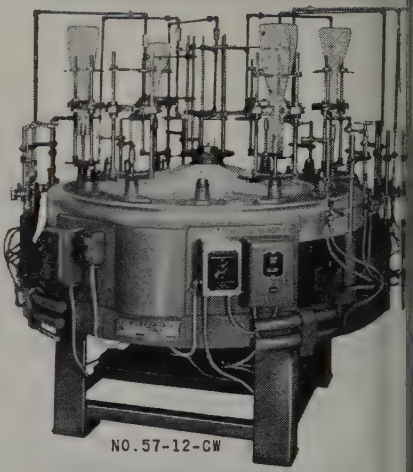
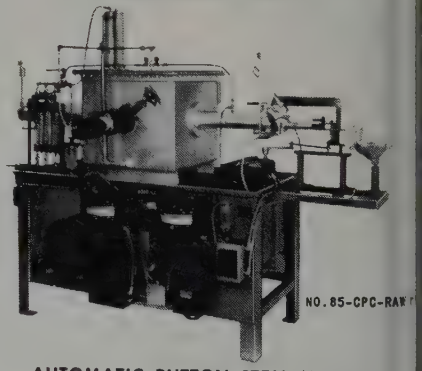
EISLER... a name to re
member in GLASS WORKING MACHINERY
—Automatic and Semi-Automatic Ma
chines to suit your production needs i
the electronic and TV tube industry.

EISLER 7½ KVA PRECISION VERTICAL SPOT WELDER

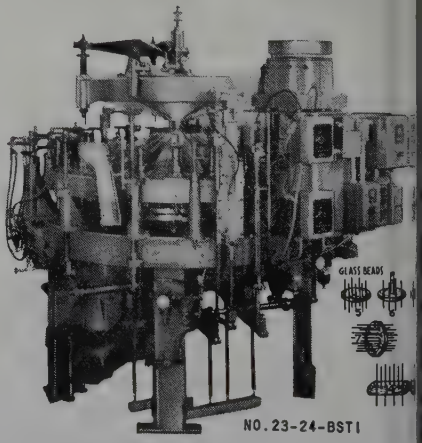
AUTOMATIC SEALING-IN MACHINE



HIGH TEMPERATURE HYDROGEN ATMOSPHERE FURNACE



AUTOMATIC BUTTON STEM MACHINE



EISLER ENGINEERING CO., INC.
766 So. 13th St., Newark 3, N.J.

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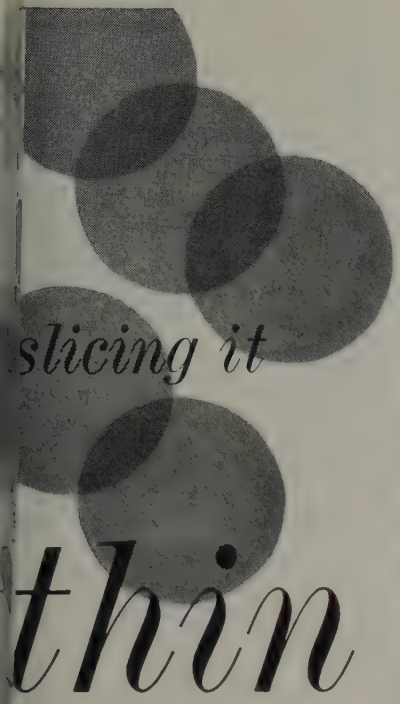

slicing it

thin

To the layman, slicing it thin suggests getting a job done just before the deadline . . . or trying to make a little bit go a long way — like dividing an apple pie among a dozen hungry boys.

In the materials processing field, slicing it thin is different — it's a condition much to be desired.

As a matter of fact, the ability to produce silicon slices of the exactly correct micrometer thinness is what separates the men from the boys.

And when it comes to slicing it thin, Semiconductor Specialties Corporation offers positive results of above average yield to users of its service.

Semiconductor Specialties is equipped to process silicon, germanium, quartz, ferrites, ceramics, intermetalics, III-V compounds, and other exotic materials.

slicing, lapping, etching, dicing, sizing, special shapes.

SEMICONDUCTOR SPECIALTIES CORP.

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PRescott 3-6933

Circle No. 48 on Reader Service Card

Dow Industrial Service four-page pamphlet, entitled "Foam," discusses new technique of cleaning industrial equipment, utilizing lightweight foamed solvent for greater efficiency, economy.

Circle 105 on Reader Service Card

The Cleannaire cabinet, for use wherever a dust-free environment is required in precision and high reliability operations, such as white rooms, laboratories and model shops, is described in a new brochure made available by Plastigage Corporation.

Circle 167 on Reader Service Card

A new technical specification bulletin describing a precision voltage source is available on request from Electronic Development Corp. (EDC). The new bulletin provides complete operating and specification data on the new Model VS-111 precision Voltage Source, which features an extended *d-c* output voltage range of ±111.11 volts, selectable in 10 millivolt steps.

Circle 168 on Reader Service Card

Valor Instruments, Inc., 16-page catalog describes a complete line of high efficiency, compact, highly regulated *d-c* power supplies. The design principles used to achieve the extremely high efficiency of 80% is explained. The complete line of 90 supplies includes modular, rack and cabinet models with outputs up to 30 amperes and 60 volts and regulations of 0.01% and 0.1%.

Circle 169 on Reader Service Card

The availability of a new short-form catalog covering its line of silicon power transistors and silicon glass diodes has been announced by Silicon Transistor Corp. The new brochure, lists STC's line of intermediate and high power transistors and a JEDEC and STC types cross reference chart.

Circle 170 on Reader Service Card

The new 1961 short form catalog covering the 22 major regulated power supplies designed and manufactured by Harrison Laboratories, Inc., is now available for industry. The catalog, covering the latest developments in regulated transistorized power supplies lists complete specifications and latest engineering features.

Circle 171 on Reader Service Card

Various kinds of corrosion and the different metals suited to resist them are given a thorough review in "Harper Corrosion Guide," a 24-page illustrated brochure published by the H. M. Harper Company. Written to help manufacturers build corrosion resistance into their products and properties, the guide analyzes the seven basic types of corrosion and shows what specific kinds of metals best resist them.

Circle 172 on Reader Service Card

A new six-page brochure, Bulletin V-125, describes the expanded line of low vapor pressure brazing alloys produced by Western Gold and Platinum Co. Specification charts detail the composition of a wide range of alloys produced specifically for use in high-vacuum electronic applications and available in wire, sheet, ribbon, powder, preforms and the new Flexibraze, a special slotted strip that provides economy for research lab and production work.

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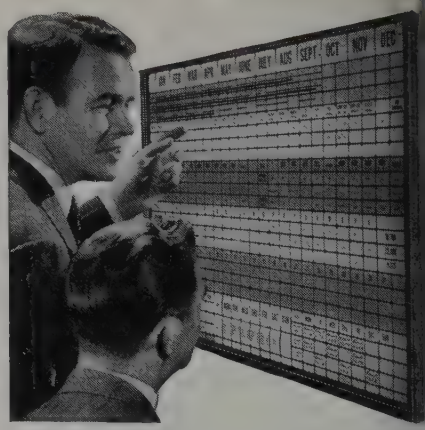

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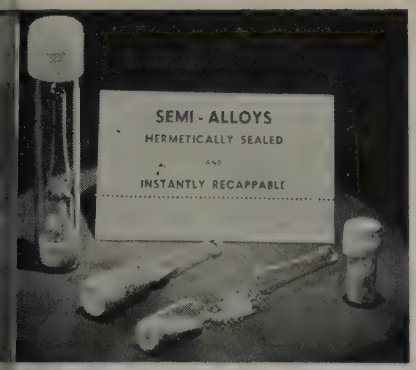

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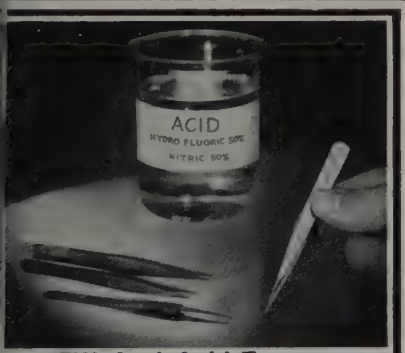

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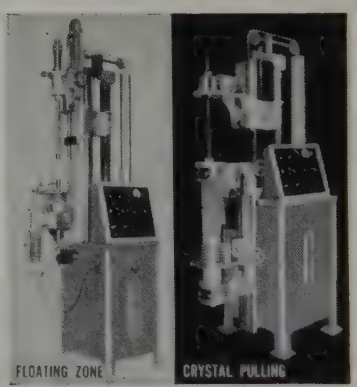

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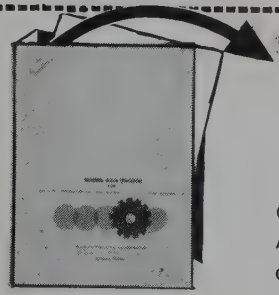

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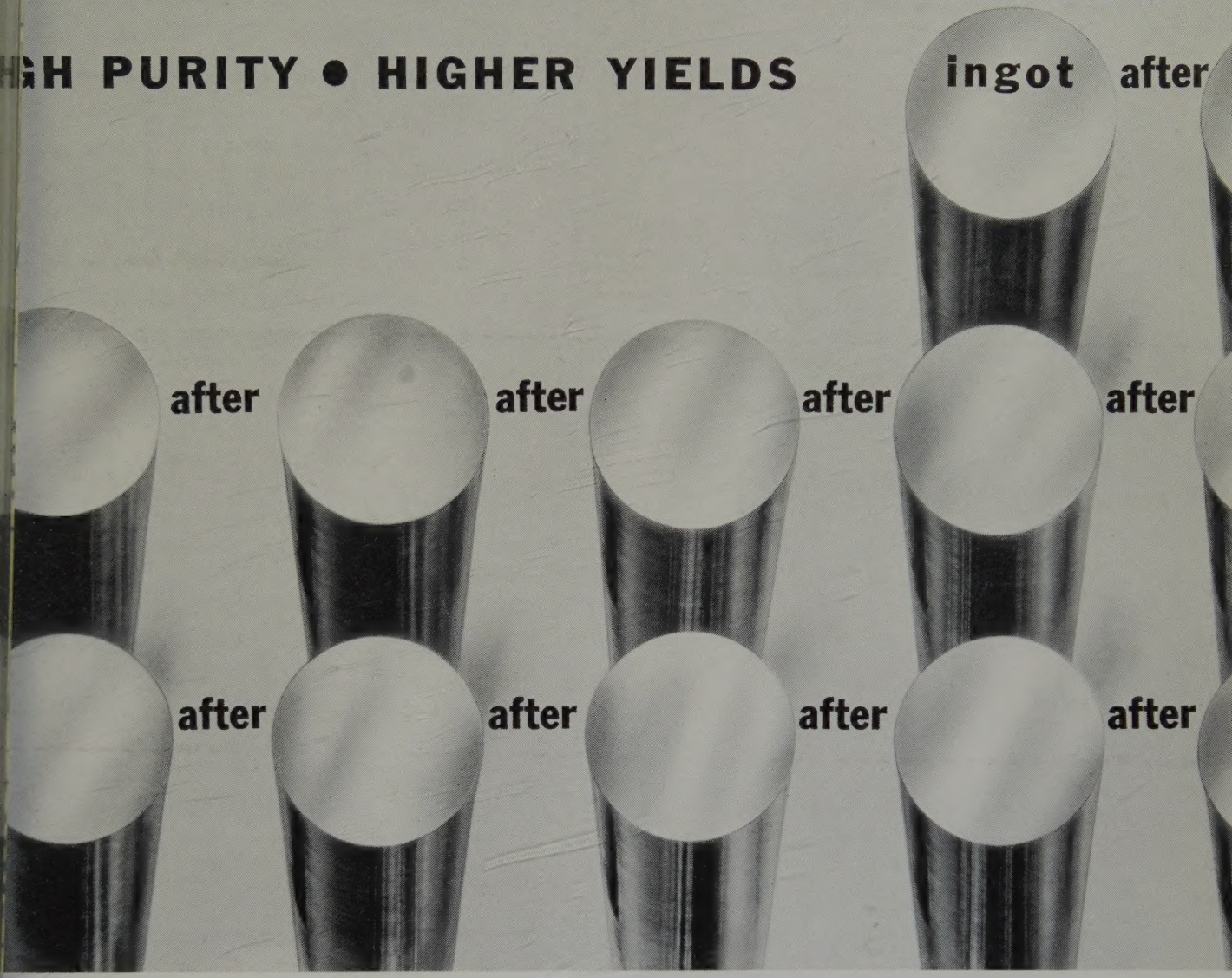

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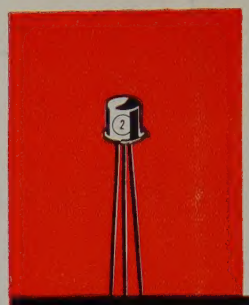

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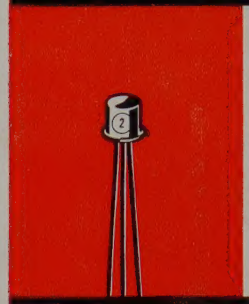

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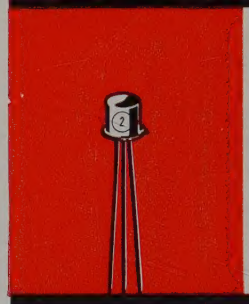

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- Manufactured with tighter parameter control than any other transistor in the industry
- Designed to meet rigid specifications of 16 electrical characteristics—ideal for NOR logic and other super-critical applications
- Low saturation voltage—typically 0.09 volts
- Higher in performance, lower in price than mesa transistors with lesser specifications

High-speed switching transistors in TO-18 cases are now being mass-produced by Sprague. These hermetically-sealed germanium Micro-Alloy Diffused-base Transistors are made by a controlled-etch process to insure extreme uniformity. Maximum frequency capabilities have been improved by graded-base construction. Automated manufacturing techniques have brought about increased production efficiency, permitting favorable reductions in prices. This is why Sprague MADT Transistors can offer you greater performance per dollar than other high-speed devices in low-current switching circuits.

Other Sprague Micro-Alloy Diffused-Base Transistors

TYPE	APPLICATION
2N499	Amplifier, to 100 mc
2N501	Ultra High Speed Switch (Storage Temperature, 85 C)
2N501A	Ultra High Speed Switch (Storage Temperature, 100 C)
2N504	High Gain IF Amplifier
2N588	Oscillator, Amplifier, to 50 mc

For complete engineering information on the types in which you are interested, write Technical Literature Section, Sprague Electric Company, 467 Marshall Street, North Adams, Massachusetts.

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